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DISEASE OF ABERRANT INTRATHORACIC LUNG TISSUE

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TWO cases of aberrant malformations of the lung, which gave rise to clinical symptoms, serve as the basis for this report. Anatomically, pathologically, and clinically this type of abnormality can be separated from the more common accessory type such as congenital cystic disease. Even this latter type only recently has come to be recognized rather frequently and proved to be clinically important. Presumably the first case was reported by Bartholinus in 1687 (Oughterson and Taffel[1]). In 1925 Koontz[2] was able to collect less than 108 cases, all discovered at autopsy. The past decade has added 152 cases (King and Harris[3]). In 1937, Schenck[4] collected 381 cases, 145 being reported in the last two years. This delayed and rapid increase seems to have followed the recognition of their clinical importance. On the other hand, this is not true of the aberrant type of malformation of which respiratory cysts in the mediastinum and aberrant lobes are outstanding examples. There has been no notable increase in reported instances since the first by Rektorzik[5] in 1861. Most are incidental autopsy findings, especially in infants.

Jacobaeus[6] reported a benign tumor resected by Key which had caused pain and dyspnea and which apparently arose from embryonic lung. Its relation to the remaining lung could not be determined. In all probability similar cases have been encountered in other clinics. Occasionally an absolute diagnosis cannot be made, and what preoperatively was regarded as a mediastinal dermoid or an intrathoracic neurofibroma proves to be a cystic or collagenous mass containing respiratory epithelium. More often than not, unlike the accessory type, a definite relation to a certain lobe or to the tracheobronchial tree is absent or obscure.

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As the frequency of exploratory thoracotomies increases, more similar cases will be encountered; therefore, a better knowledge of malformations, particularly aberrant lobes, may be helpful in the provision of accurate diagnosis and suitable treatment. The following is a discussion of the development and peculiarities of various anomalies and an attempt to set forth a definite relationship between the anatomical and clinical features of certain types. Three illustrative cases are reported.

MALFORMATIONS

The constancy of the tracheobronchial pattern (Schaffner,[7] Neil et al.[8]) and fissure formation seems only less remarkable than the infrequency of anomalies. A general understanding of the processes which take place in the development of the lungs and the closure of the body cavities is essential for the comprehension of pulmonary anomalies but does not always supply adequate explanation for their occurrence. It is beyond the scope of this contribution to review the normal embryology. Worthy of mention, however, is the work of Palmer[9] who has studied the histology of the lungs of human embryos from a total length of 11 mm. to a crown-rump length of 170 mm. He counted the tubular divisions by designating the primary bronchus as generation one, tracing it by serial sections until its first branch which was regarded as generation two, and so on. The total number of generations was seventeen reached by four and one-half to five months of fetal growth and not increasing through the sixth month. At this time the entodermal lining of the tracheobronchial tree loses its continuity by the intrusion of naked capillary loops into generations fourteen, fifteen, and sixteen, which also show evidence of further branching and which represent the immature respiratory units of the lung. Bronchial glands seem to disappear after the fifth generation, cartilage after the seventh; the epithelium becomes simple in the eighth and cuboidal in the eleventh. Cilia appear no more after the tenth generation in the fetus studied by Palmer.

Just as a failure of fusion of the right and left halves of the somatopleure gives rise to ventral defects and herniae, the failure of fusion of the transverse septum with the pleuropericardial membrane or the pleuroperitoneal membrane produces pericardial defects and diaphragmatic herniae. If the laryngotracheal grooves fail to occur, absence of the trachea follows; if their development is defective or arrested, tracheoesophageal fistula, atresia, or a double trachea might result. Occasionally, after the bifurcation of the tracheal bud, one limb fails to develop, resulting in agenesis (Gross[10]) such as reported by Hurwitz and Stephens[11] who collected 34 cases. In most of these instances, a small bronchial stump represented an entire lung. One case lived 72 years. Scheidegger[12] states that agenesis usually does not cause symptoms during life. Elward[13] discusses the difficulties of roentgenologic diagnosis.

Other anomalies are not so readily understood even with a thorough knowledge of the normal embryology. Any explanation that will fit the facts of known anomalies must be based on presumption and theory until a method of actual investigation comes to hand. Thus, if the potency of a given germ layer is presumed to continue throughout its development, a theory can be formulated. Cysts of the esophagus (Kern[14]), liver (von Recklinghausen[15]), and mediastinum (Stilling[16]) lined with ciliated epithelium do not seem so extraordinary if one presumes that entodermal cells of the foregut may produce such structures even though they are not included in the bud destined to be the lungs.

How the hepatic system arises from an entodermal pouch in the mesenchyme of the transverse septum is known; if a portion of this bud developed ciliated epithelium rather than bile ducts, or an extra bud occurred from the foregut and gave rise to respiratory tissue in mesenchyme destined to become liver stroma, certainly a liver cyst of ciliated epithelium might be forthcoming. It does not seem illogical to presume extra foregut or tracheal buds pushing into mesenchyme and giving rise to foregut derivatives; remaining attached to their parent structures or separated; connected to the trachea, esophagus, stomach; or isolated in the mediastinum, pleural space, or costophrenic sinus. Nor does the separation of a portion of a primitive anlage or the isolation of such a structure by encroaching mesenchyme seem without the realm of possibility. However, in such an instance a defect in the derivative of the anlage can be rightfully expected. Neither the primitive foregut nor the early lung anlage can be eliminated as the origin of anomalous structures; probably both are responsible.

The mechanism of the production of malformations concerns this contribution only so far as it is helpful in understanding clinical states which may arise from their presence and which arbitrarily divide anomalies of entodermal origin into two groups. The first is prone to give rise to distressing symptoms; the second tends to remain clinically silent and to be revealed incidentally by x-ray or autopsy. This clinicoanatomical division depends on the presence or absence of a tracheobronchial communication and is best designated by the terms accessory and aberrant respectively. The bronchial communication is not the only differential feature, but it is responsible for the production of the diseased states common to the accessory form, while aberrant forms may give rise to diseased states by other means.

ACCESSORY TYPES

Tracheal Diverticula. Tracheal Accessory Lungs.—Small diverticula arising from the trachea usually on the right side near the bifurcation have been described by Chiari.[17] Their wall structure simulates that of the trachea; they have been regarded as evidence of a triple bifurcation

and also as misplaced rudimentary apical bronchi. They have not, as yet, proved to be clinically important. However, their presence could produce a very disturbing as well as a diagnostic bronchogram.

Herxheimer[18] and Muller[19] have reported tracheal accessory lungs, small masses of well-developed lung tissue communicating with the trachea through separate bronchi and located high in the mediastinum lateral to the trachea. Leroux[20] reported a similar case discovered by bronchoscopy and subsequently filled with lipiodol. The lung described by Herxheimer was the seat of a catarrhal pneumonia; in general, this type can clinically be classed with the following.

Bizarre Fissure Formation. Azygos Lobes. Inferior Accessory Lobes.—The constancy of the pattern formed by the normal primary, secondary, and even tertiary bronchial stems was referred to in the discussion on embryology. If these structures do not quite conform to the usual pattern, there is often no evidence of such irregularity on the pleural surface. Occasionally, however, the misplaced branches are accompanied by accessory lobes and bizarre fissures, a fact taken into account in the theory suggesting the lung anlage itself as the source of anomalies. An accessory lobe in such an instance would be expected, especially if the abnormal bronchial stem was an early or central one, for these divisions apparently push their own separate mesenchymal mass before them.

Intact accessory lobes in fully developed lungs do not cause particular concern, for in life they function and behave as the remainder of the lungs in normal as well as diseased states. Farrano[21] is inclined to regard them as more susceptible to pathologic processes. In 5,612 roentgenograms of the chest, he found 28 or 0.5 per cent azygos lobes; 16 of these were regarded as pathological, that is, tuberculous, cavitated, atelectatic, or pleuritic. Soper[22] found 13 or 0.8 per cent azygos lobes in 1,600 student roentgenograms. He discusses the radiologic diagnosis in normal and diseased states. Harrington[23] reported the excision of a cystic azygos lobe; Marfori,[24] a case of an 11-month-old female infant dying of bronchopneumonia with four lobes in the right lung, three in the left, and, in addition, an aberrant lobe with a stalk to the mediastinum. Epplen and Jacobson[25] described an accessory lobe which was floating in a hydrothorax of cardiac failure in a 70-year-old white male. The pedicle of the lobe had been twisted two and one-half turns, resulting in most severe hyperemia.

Bronchiogenic Cysts. Congenital Cystic Disease.—In contrast to the aberrant type of malformation, this anomaly is now frequently reported largely because of the recent recognition of its clinical importance. Many cases and many theories of disturbed embryology are found in the literature (Koontz[2]). Heuter[26] proposed bronchial stenosis or closure with retention of secretions as the cause. This explanation is favored by King

and Harris[3] who emphasized the importance of a valvular obstruction which they attributed to faulty canalization of solid entodermal bronchial radicals. They also believe that such anomalies occur rather late in the embryonic period and that, being a part of the lung itself, the affected lobe indicates the cyst origin. On the basis of Palmer's[9] work, it seems possible that whether the cyst will contain air or fluid may depend upon which generation of bronchial radical canalized defectively. It will contain fluid before the fifth generation and air after, according to the presence or absence of mucous glands in the involved generation. Single large cysts frequently call for surgical treatment (Harrington,[23] Oughterson and Taffel[1]). The problem of cystic disease as a whole is well known to thoracic surgeons.

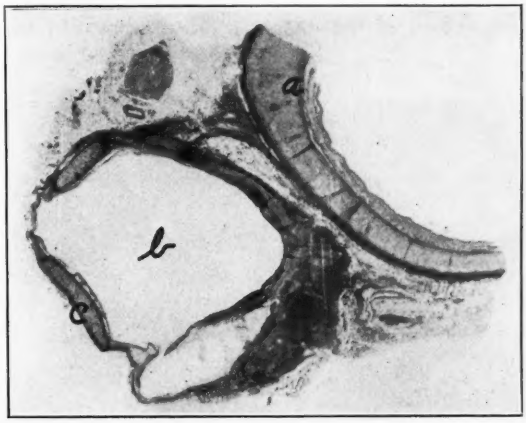

Fig. 1.—Bronchial cyst measuring 1 cm. in diameter and approximating left main bronchus found at autopsy by Dr. S. Koletsky at Cleveland City Hospital: *a*, cartilage of left main bronchus; *b*, entire cyst; *c*, cartilage of cyst wall. Mucous glands were also present.

ABERRANT TYPES

Cysts of Respiratory Epithelium in the Mediastinum.—Scheidegger[12] embryologically classed this form with tracheal diverticula and tracheal accessory lung. It is most frequently reported as occurring near a major bronchus, especially on the right side. Fig. 1 is an example of one occurring on the left, such as reported by Hammar.[27] Stilling[16] discovered a larger one in the anterior mediastinum. Gold[28] reported four cases and regarded them as rudimentary bronchial stems. Chiari,[17] Herxheimer,[18] Muller,[19] and Scheidegger[12] are in apparent agreement. These cysts are usually thin-walled, lined with ciliated epithelium, columnar or flattened, occasionally lacking cilia. The mesenchyme contributes the rest of the cyst wall. Rarely, cartilage, elastic tissue, muscle, and mucous glands are all present in fairly normal proportion (Fig. 1). The cyst in one of Gold's cases extended well down toward the middle lobe bronchus

and caused a concavity in the lower lobe; in another, it was quite large and caused severe obstructive symptoms (Fig. 2). These cysts are usually filled with debris, desquamated epithelium, and mucoid material. In none of the cases reviewed was a bronchial communication demonstrated. The tracheobronchial tree is most often normal. It is likely that mediastinal cysts of this nature represent maldeveloped and separated portions of the primitive lung anlage.

Their location, adjacent to main bronchi and large blood vessels, affords a potential danger of obstruction should enlargement occur. The number of cases in which an increase in size does take place is small; however, so is the number of recorded instances. Therefore, it is impossible to estimate or foretell the risk entailed by their uninterrupted presence. This anomaly may cause cough, chest pain, dyspnea, or obstructive symptoms. An associated inflammatory process (Case 3) may in itself cause symptoms or produce enlargement or pleural effusion.

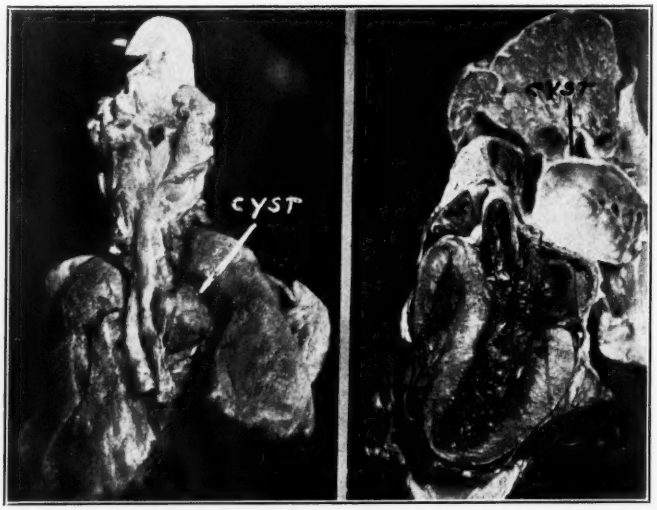

Fig. 2.—Bronchial cyst of mediastinum occurring in a child and causing obstructive symptoms. (From Gold.) Courtesy Gustav Fischer, Jena.

It is likely to be revealed in chest roentgenograms where it simulates other fluid cysts, such as dermoids, bronchiogenic cysts, and pericardial diverticula. In addition, it may be confused with solid tumors.

Aberrant Lobes.—Carter and Osborn[29] suggested the term aberrant rather than accessory or supernumerary, which are usually used to designate this condition. Koontz[2] in his list of 108 cases included twelve of aberrant lobes and noted the authors of fifteen more. Before this, Rokitansky[30] in 1861 collected thirteen cases. Others are reported by Marfori,[24] Scheidegger,[12] and Carter and Osborn.[29] In all probability

many more have been encountered but have not been reported because they are still regarded interesting rather than significant (Marfori,[24] Scheidegger[12]).

This anomaly is most commonly found in the left chest, particularly between the lower lobe and diaphragm (Fig. 3). Vogel[31] reported two situated beneath this structure. Often they are accompanied by other anomalies and are incidental autopsy findings in the newborn. Invariably they have a smooth, free pleural surface and no communication with the tracheobronchial tree. As a rule a stalk of areolar connective tissue attaches them to neighboring structures, particularly the mediastinum near the esophagus, but also to the lower and upper lobes, diaphragm, and even the stomach. In Scheidegger's case the stalk contained gastric mucosa and coursed through the diaphragm to communicate with the stomach lumen. The stalk bore the blood and nerve supply through the diaphragm in the instance reported by Carter and Osborn.

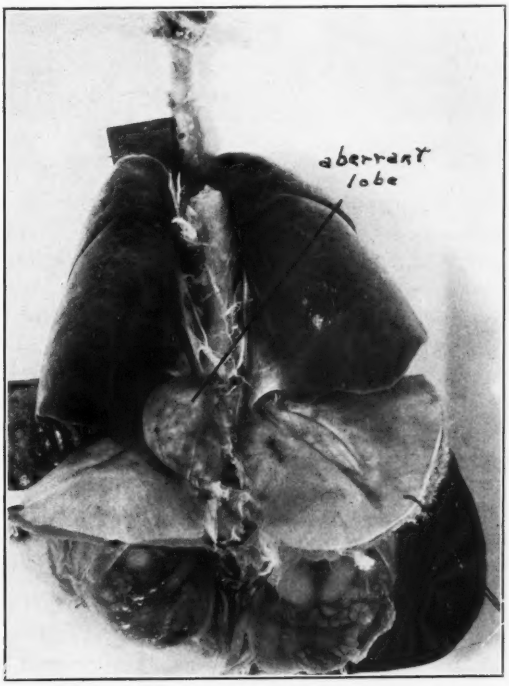

Fig. 3.—Case 1. Aberrant lobe in left posterior mediastinum. Also polycystic kidneys.

These structures are usually rich in dilated bronchial radicals, often forming large cysts lined with cuboidal ciliated epithelium (Fig. 4). Cartilage is frequently absent or occurs only as irregular plates. Smooth muscle is usually present but often scanty. Elastic tissue is present in

varying amounts. Frequently there is no alveolar structure, and the cystic changes are so marked that the recognition of lung tissue is difficult. The blood supply is usually from the thoracic aorta by way of the stalk which also carries the venous drainage to the azygos system.

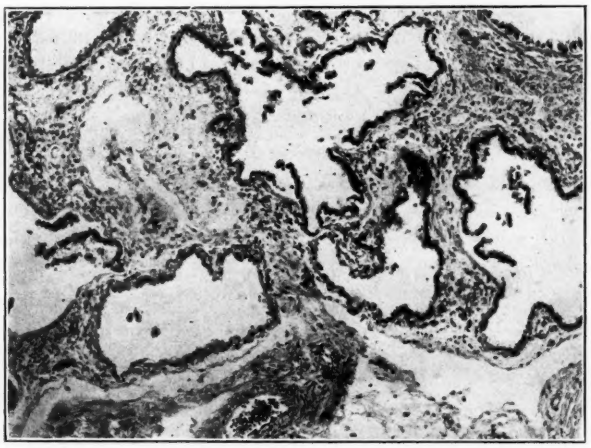

Fig. 4.—Case 1. Hematoxylin and eosin. ×70. Note dilated bronchial radicals and ciliated cuboidal epithelium. Compare with Fig. 7, Case 2.

The entoderm is undoubtedly the origin of these structures, but there is some confusion as to whether they arise from the primitive foregut which very early is lined with ciliated epithelium or from the respiratory anlage. Scheidegger[12] described the excess and the fractional theories: the former assumes an extra bud from the foregut or a third lung anlage; the latter supposes the separation of a portion of developing anlage at a later stage. The preponderance of left-side cases and paraesophageal stalks, the usual presence of a systemic blood supply, and the cases communicating with the stomach (Scheidegger[12]), along with the constant absence of a bronchial communication, support a primitive foregut origin. It is quite likely that abnormal or additional structures are responsible for aberrant lobes. While the above facts favor the foregut as parent, they make an explanation for right-side cases with pedicles attached to the lung even more difficult, especially when the anomaly is accompanied by a defect in the neighboring lung. The mesenchyme is probably responsible for the stalk, its position and blood supply once a nest of entodermal cells is isolated within it whether they arise from foregut or lung anlage.

This anomaly, like the one before, is isolated from infection by way of the tracheobronchial tree in contradistinction to the accessory type. However, it may become the seat of an inflammatory process through the blood or lymph stream (Case 2). In addition, it may produce symptoms in the same ways as aberrant cysts. In fact, considering the constant

cystic changes, sometimes very severe, noted within these aberrant lobes, complete cystic degeneration is a possibility with the production of an epithelial lined fluid mass. Case 3 might possibly represent such an instance. Accessory lobes and agenesis can be diagnosed by the roentgenogram (Farrano,[21] Thorpe,[32] Elward,[13] Soper[22]), but aberrant lobes have no known typical picture unless they contain much fluid or are altered by disease.

Table I summarizes the differentiation of accessory and aberrant types of malformations.

TABLE I

DIFFERENTIATION OF ENTODERMAL MALFORMATIONS

FEATURE	ACCESSORY	ABERRANT
Embryologic	Due to faulty development of lung anlage early or late.	Due to faulty development of lung anlage. May also arise from primitive foregut.
Clinical	Frequently cause symptoms.	Rarely cause symptoms.
	Diagnosis can usually be made by x-ray, bronchoscopy, or bronchography.	Diagnosis usually by thoracotomy.
	Usually has to be differentiated from an inflammatory process.	Usually has to be differentiated from benign tumors.
Pathologic	Infection frequently occurs by way of the bronchial communication.	Infection is rare, but may occur by lymph or blood streams.
Anatomical	Always intrathoracic when pleural cavity is intact.	May be extrathoracic.
	Blood supply is that of lung.	Blood supply usually systemic.
	No stalk.	Stalk present.
	Forms a portion of existing lung.	Separate from existing lung.
	Communicates with tracheobronchial tree.	No communication with tracheobronchial tree.
	Usually contains all tissue elements of normal lung.	Cartilage, muscle, and mucous glands may be absent.

There are other intrathoracic malformations of considerable interest which do not belong in the above distinction, such as those of pure mesenchymal origin (Zipkin[33]). Mediastinal teratomas arising from all three germ layers ordinarily represent fusion enclosures, and, clinically and radiologically, are little different from the aberrant types except for their tendency to become malignant. As pointed out by Smith and Mills,[34] they should be differentiated from dermoid cysts which are ectodermic in origin, usually in the form of a single cyst, and do not exhibit malignant tendencies. These are even more likely to be clinically confused with aberrant malformations. Additional interesting anomalies are tumor-like malformations as described by Koboth[35] who reported six cases, one her own, of supernumerary lobes of the lung in which there were six features common to all, namely: replacement of an entire lobe; bronchus absent, blind, or could not be traced (in Koboth's case, the lobe contained air); all occurred in newborn infants; all contained epithelium besides the respiratory type; all had similar gross characteristics; and all had dilatation of the bronchial spaces. Favre and his

associates[36] reported five cases of nodular formations of the lung, single and multiple, all discovered at autopsy in adults. They consisted of connective tissue, epithelium, cartilage, and adipose tissue. In a discussion of their etiology, benign tumors, malformations, and inflammatory productions are mentioned. Favre et al.[36] favor the latter. The structures described by them and Koboth may not be anomalies, and they are truly neither accessory nor aberrant.

CASE REPORTS

CASE 1.—Baby girl G., a 7-month premature child, colored, weighing 1215 gm., was admitted after delivery to the University Hospitals, Western Reserve University, Oct. 21, 1934, and died soon after admission evidently from prematurity. Autopsy performed 44 hours after death by one of the authors (P. W. G.) revealed polycystic kidneys and an intrathoracic aberrant lobe between the diaphragm and left lower lobe (Fig. 3). There was a large concave defect in the left lower lobe. A thin areolar tissue stalk connected the lobe to the mediastinum near the esophagus. There was no bronchial communication. The tumor (Fig. 4) consisted of dilated bronchial radicals lined with ciliated cuboidal epithelium. Mucous glands, cartilage plates, and alveolar structures were not encountered. Special stains revealed a normal elastic tissue content and a scarcity of smooth muscle.

This is an instance of true aberrant lobe. It is quite likely that its presence contributed very little to death. If this baby had lived, the aberrant lobe may never have been discovered. On the other hand, there is the possibility that it would have enlarged by growth or the accumulation of secretions enough to cause symptoms. In addition, it would have been susceptible to infection through the lymph or blood streams. The appearance of an aberrant lobe as an innocent structure in a dead baby is not sufficient reason to believe that it would have remained such had the baby lived.

CASE 2.—G. R., white female, 21 years of age, entered Cleveland City Hospital, May 6, 1936, with a history of occasional precordial pain and palpitation, progressive weakness, nonproductive cough, and a 30 pound weight loss of six months' duration following childbirth. Frequent night sweats had occurred for two months.

Physical examination revealed the temperature to be 38° C., pulse 90, blood pressure 115/65. There was evidence of weight loss and weakness, signs of mediastinal widening to the left, and diminished breath sounds anteriorly over the left upper lobe. The spleen was barely palpable. A small lymph node could be felt in the left axilla. Urinalysis was negative. The Wassermann test was negative. The blood showed red blood cells 4.09, hemoglobin, 90 per cent, white blood cells 17,500, 71 per cent polymorphonuclears. Roentgenograms disclosed a dense mass in the medial left upper lung field, calcified nodes in the right hilus, and a calcified nodule in the periphery of the right lung (Fig. 5*a*).

Course.—A low-grade fever and dry cough persisted. Tentative diagnosis was lymphoblastoma. Lymph node biopsy revealed endothelial hyperplasia. On the tenth day a series of six x-ray treatments was started, each 200 r. The mass did not change in size. On the seventeenth day 15 gm. of tenacious, homogeneous, pale yellow material containing small calcareous masses were expectorated. Smear disclosed necrotic material, no pus cells, no acid fast or other organisms. The amount of sputum increased to as high as 60 gm. Repeat roentgenograms revealed a fluid level (Fig. 5*b*). The clinical impression was cystic teratoma which had perforated a bronchus.

Operation.—After the induction of pneumothorax, exploratory thoracotomy was done (by S. O. F.) on the thirty-eighth hospital day through the left third interspace anteriorly. A pyramidal mass (Fig. 6) covered with a thin glistening membrane, dark-red in color, was found anteriorly, separating an atelectatic upper lobe from the mediastinum and approximating the lower lobe and pericardium. It was bluntly separated without difficulty except at the left hilus where it was more densely adherent and removed. No bronchial communication could be demonstrated. Except for collapse, the upper and lower lobes appeared normal. Postoperatively

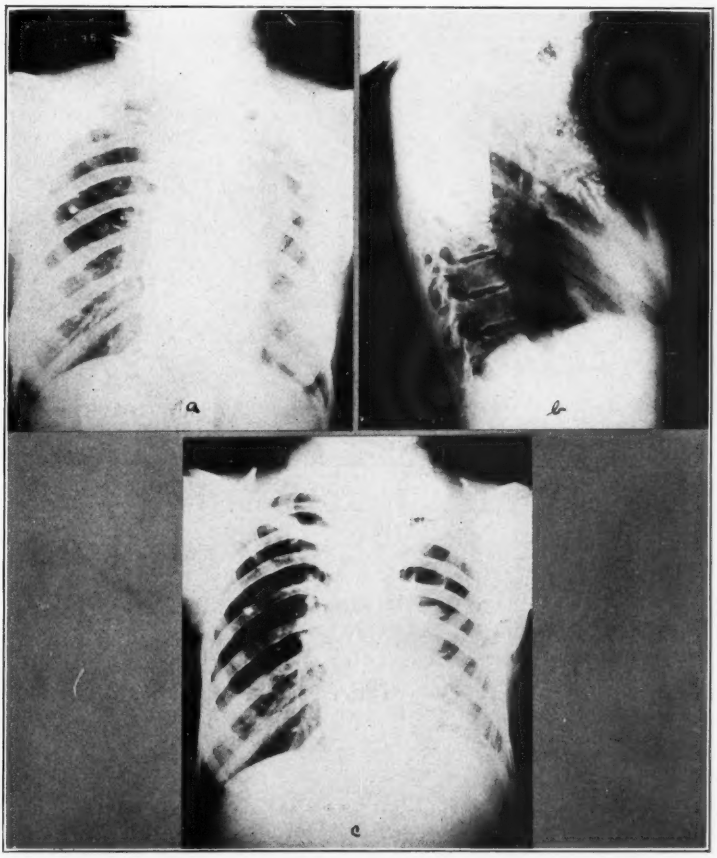

Fig. 5.—Case 2: *a*, shortly after admission; mass upper left mediastinum; *b*, after x-ray treatment and perforation of bronchus, cavitation evident and calcification marked; *c*, three weeks after excision, chest completely healed.

there was no evidence of a bronchial fistula. The patient made an uneventful recovery (Fig. 5*c*), and was discharged on the twenty-third postoperative day. The patient was followed for two months in the Outpatient Department. There was a gradual weight gain and no symptoms. Since then there has been no response to follow-up inquiries.

Pathologic Examination.—Cut section (Fig. 6) revealed numerous small intercommunicating cavities with an average size of 1 cm. in a rather soft mass of trabecular architecture. There were numerous clusters of calcified material. Microscopically the mass consisted of atelectatic embryonic lung tissue, the seat of a destructive granulomatous process which histologically was active conglomerate tuberculosis with typical Langhans giant cells; however, tubercle bacilli could not be demonstrated. In areas (Fig. 7) there were closely packed, branching, cystic, rudimentary bronchial radicals lined with cuboidal epithelial cells; elsewhere there were well-developed alveoli. The stroma consisted of fibromuscular tissue. Mucous glands and cartilage plates were rarely seen. The pathological diagnosis was "atelectatic

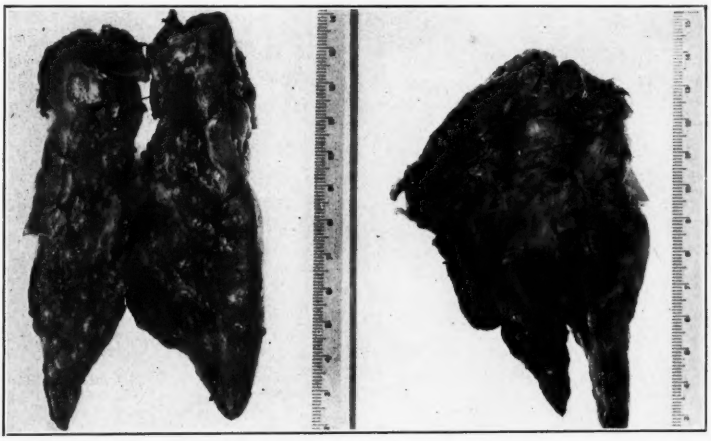

Fig. 6.—Case 2. Appearance of aberrant lobe after removal. Note trabecular architecture on cut section. (See Fig. 7.)

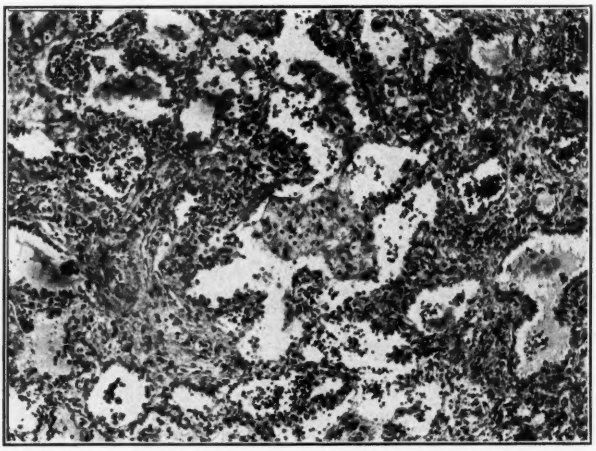

Fig. 7.—Case 2. Hematoxylin and eosin section. ×70. Diffuse infiltration of inflammatory cells. Note dilated spaces lined with ciliated columnar epithelium as in Case 1. (Compare with Fig. 4.)

congenitally malformed lung showing active conglomerate tuberculosis with numerous areas of calcification.'' The similarity to Case 1 (Figs. 4 and 7) is evident despite the diffuse infiltration of inflammatory cells.

This was undoubtedly a case of diseased aberrant lobe. The long period of irritative cough without expectoration and the operative findings supported the absence of a bronchial communication. Caseation, which was possibly enhanced by irradiation, probably led to perforation and consequent sputum, especially since, microscopically, that portion of the lobe not the seat of cavitation was atelectatic, indi-

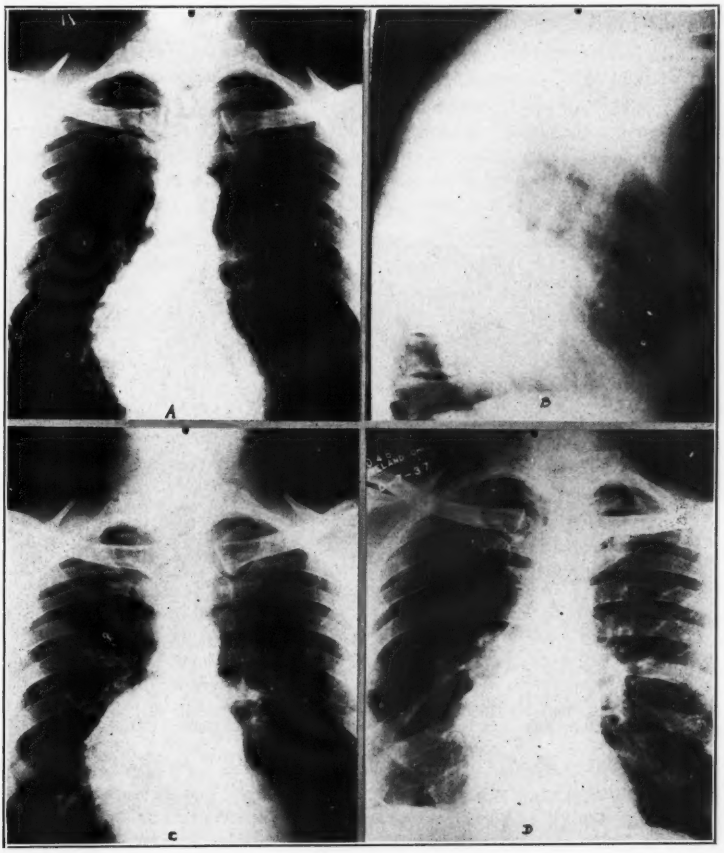

Fig. 8.—Case 3. *A* and *B*, anteroposterior and lateral views of aberrant cyst in 1930. *C*, some enlargement 7 years later. *D*, six weeks after excision of cyst.

cating that only the cavity communicated with the bronchus. The degree of calcification may be an expression of the effect of irradiation, or it may be the monument of an older arrested infection which was stirred to activity by childbirth.

Case 3.—F. L., white male, aged 53 years, entered Cleveland City Hospital Aug. 8, 1937, complaining of pain in the right lower chest, dyspnea, and cough. The present illness began 25 years previously with a dry cough. A roentgenogram taken

in 1917 revealed a "mediastinal shadow on the right side separate from the heart shadow." This was not diagnosed. In spite of a negative Wassermann test, six injections of salvarsan and bismuth were administered with no effect. Roentgenograms were repeated in 1930 (Figs. 8*a* and *b*) and a diagnosis of mediastinal dermoid cyst ventured. From this time there was a gradual increase in symptoms until a few weeks before admission when dyspnea became troublesome. Roentgenograms showed an increase in the tumor size (Fig. 8*c*). A few days before admission the patient experienced excruciating pain and severe dyspnea. There was no history of hemoptysis or weight loss. The patient had noted a wheeze at times and was subject to frequent colds.

Physical examination revealed an expiratory wheeze, no vocal cord paralysis, signs of fluid in the right chest, and mild pulmonary emphysema. Temperature was 37° C., pulse, 80, blood pressure, 130/80.

Laboratory.—Urinalysis was negative, red blood count 4.8, hemoglobin 70 per cent, Wassermann test negative, sputum negative for tubercle bacilli, electrocardiogram normal. Roentgenograms revealed a right pleural effusion and a shift of the barium-filled esophagus to the left and posteriorly.

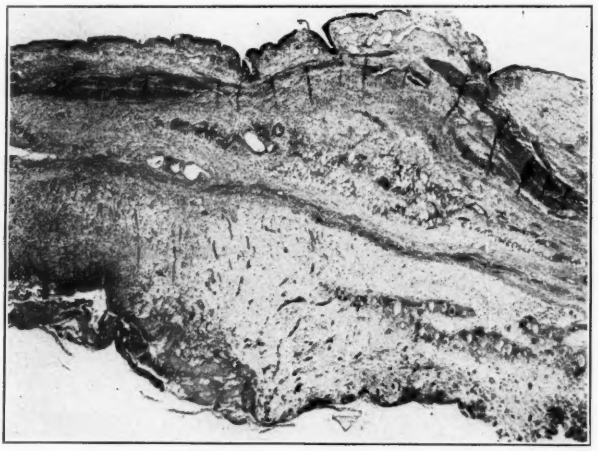

Fig. 9.—Case 3. Hematoxylin and eosin. ×12. Section of cyst wall showing diffuse infiltration of inflammatory cells, respiratory epithelium, and strands of smooth muscle.

Course.—1600 c.c. of sterile straw-colored fluid in the right chest was replaced with air. Bronchoscopy was not done because of dyspnea. Repeated roentgenograms showed the mass to be intact and the pleural space partially free. The fact that in 1917 the mass was separate from the heart shadow was not known at this time, and the clinical impression was mediastinal teratoma or pericardial diverticulum of the congenital type.

Operation.—Exploratory thoracotomy (by S. O. F.) on the eleventh hospital day was carried out by resection of the eighth right rib and division of the ninth. A spherical cystic mass, approximately 15 cm. in diameter, was found arising from the lower mediastinum. It displaced the lower lobe anteriorly and inferiorly and the middle and upper lobes anteriorly and upward. While adherent to these structures, it was separable and did not seem to be a part of the lung. Overlying the pericardium, it was quite thin and inseparable. There was apparent compression of

the inferior pulmonary vein in the pulmonary ligament. There was no bronchial or pericardial communication. The cyst was filled with a thick, tenacious, glary, grayish-yellow material. It was excised except for the portion adherent to the pericardium. Closed intercostal drainage was instituted. The postoperative course was never stormy but protracted because of empyema. Seven weeks later a secondary infected cyst, evidently formed by the unexcised portion, was opened and packed. The cavity gradually decreased in size, and a slight fever subsided (Fig. 8*d*). A right phrenic nerve crush was done to diminish the size of the wound cavity. Bronchoscopy revealed no visible abnormality. The patient was discharged three months after operation.

Pathologic Examination was gross as above. The cyst contents on smear consisted of amorphous debris, red cells, fibrin, and polymorphonuclear leucocytes. The cyst wall (Fig. 9) was lined with ciliated epithelium of the respiratory type and contained strands of smooth muscle and connective tissue. Mucous glands and cartilage were not noted. There was evidence of subacute and chronic inflammation of the entire cyst wall. The pathological diagnosis was "mediastinal cyst arising from respiratory anlage."

It is unlikely that the degree of inflammation exhibited microscopically was a cause for symptoms; it may have been responsible for the late pleural effusion. Undoubtedly the cyst itself had caused symptoms for 25 years. These were increased in severity during a period in which known enlargement occurred. It seems that symptoms can arise from the location of the cyst by causing bronchial irritation, or by pressure on vessels, from enlargement secondary to retained secretions or growth, and from accompanying effusion as well as from inflammation.

CONCLUSIONS

1. Intrathoracic malformations consisting of lung tissue theoretically can arise from the primitive foregut or the early lung anlage.

2. Entodermal malformations of the lungs can be classified as aberrant and accessory, depending upon embryological and anatomical features.

3. The accessory type has been recently recognized as clinically important, which has led to a rapid increase in the number of reported instances. It frequently produces distressing symptoms demanding treatment, including surgery.

4. The aberrant type is more rare. There is no recent increase in reported cases, and, heretofore, they have been regarded only as interesting.

5. Illustrative cases indicate that malformations may cause symptoms because of their location and size, by growth and pressure, by incitement of pleural effusion, and by inflammation borne by the lymph or the blood streams. Under such circumstances surgical excision is probably the proper treatment.

REFERENCES

1. Oughterson, A. W., and Taffel, M.: Pulmonary Cysts, Yale J. Biol. & Med. **9**: 77, 1937.

2. Koontz, A. R.: Congenital Cysts of the Lungs, Johns Hopkins Hosp. Bull. **37**: 340, 1925.

3. King, J. C., and Harris, L. C., Jr.: Congenital Lung Cyst, J. A. M. A. **108**: 274, 1937.
4. Schenck, S. G.: Diagnosis of Congenital Cystic Disease of the Lung, Arch. Int. Med. **60**: 1-21, 1937.
5. Rektorzik: An Accessory Lobe of the Lung, Wchenbl. d. Ztschr. d. k. k. Gesellsch. d. Aerzte in Wien **12**: 4, 1861. (Quoted by Vogel, Herxheimer, Scheidegger, and Carter and Osborn.)
6. Jacobaeus, H. C.: Intrathoracic Tumors Treated Surgically, Acta med. Scandinav. supp. **78**: 446, 1936.
7. Schaffner, G.: Inferior Accessory Lobes, Arch. f. path. Anat. **152**: 1, 1898.
8. Neil, J. H., Gilmour, W., and Gwynne, F. J.: Bronchopulmonary Segments, M. J. Australia **2**: 165, 1937.
9. Palmer, D. M.: The Lung of a Human Fetus of 170 mm. C. R. Length, Am. J. Anat. **58**: 59, 1936.
10. Gross, W.: A Case of Agenesis of the Left Lung, Beitr. z. path. Anat. **37**: 487, 1905.
11. Hurwitz, S., and Stephens, H. B.: Agenesis of the Lung, Am. J. M. Sc. **193**: 81, 1937.
12. Scheidegger, S.: Development of Malformations of the Lungs, Frankfurt. Ztschr. f. Path. **49**: 362, 1936.
13. Elward, J. F.: Roentgen Aspects of Congenital Aplasia, Radiology **27**: 667, 1936.
14. Kern, W.: Contribution on the Pathology of the Esophagus, Virchow's Arch. f. path. Anat. **201**: 135, 1910.
15. Von Recklinghausen, F.: A Cyst of Bartholin's Duct and a Ciliated Epithelial Cyst of the Liver, Virchow's Arch. f. path. Anat. **84**: 425, 1881.
16. Stilling, H.: A Ciliated Epithelial Cyst of the Anterior Mediastinum, Virchow's Arch. f. path. Anat. **114**: 557, 1888.
17. Chiari, H.: A New Type of Malformation of the Trachea of Infants, Beitr. z. path. Anat. **5**: 329, 1889; A Congenital Diverticulum of the Right Main Bronchus, Prag. med. Wchnschr. **15**: 567, 1890; A New Form of Tracheal Bifurcation, Prag. med. Wchnschr. **16**: 89, 1891.
18. Herxheimer, G.: A Case of True Accessory Lung, Zbl. Path. **12**: 529, 1901.
19. Muller, H.: Lobe Anomalies of the Lung, Virchow's Arch. f. path. Anat. **225**: 284, 1918.
20. Leroux, L.: Two Unusual Cases of Bronchoscopy, J. of Laryng. & Otol. **53**: 150, 1938.
21. Farrano, V.: Pathological Accessory Lobes of the Right Lung, Lotta contro la tuberculosi, 1937.
22. Soper, W. B.: Some Clinical Aspects of Accessory Lobes of the Human Lungs, Yale J. Biol. & Med. **5**: 227, 1933.
23. Harrington, S. W.: Surgical Treatment of Mediastinal Tumors, Ann. Surg. **96**: 843, 1932.
24. Marfori, L.: A Case of Accessory Lung, Pathologica **27**: 720, 1935.
25. Epplen, F., and Jacobson, A. L.: Twisted Pedicle of Accessory Lobe of the Lung, J. A. M. A. **94**: 1135, 1930.
26. Heuter, C.: On Congenital Bronchiectasis, Beitr. z. path. Anat. u. z. allg. Path. **59**: 520, 1914.
27. Hammar: A Case of Bronchial Cyst in an 11.7 mm. Fetus, Ziegler's Beiträge **36**: 518, 1904.
28. Gold, E.: On Bronchial Cysts, Ziegler's Beiträge **68**: 278, 1921.
29. Carter, H., and Osborn, H. A.: Case of Accessory Lobe, J. Obst. & Gynaec. Brit. Emp. **43**: 1194, 1936.
30. Rokitansky, K.: Lehrb. Path. Anat., 1861. (Quoted by Scheidegger.)
31. Vogel, R.: Two Cases of Abdominal Lungs, Virchow's Arch. f. path. Anat. **155**: 235, 1899.

32. Thorpe, M.: Congenital Cystic Lung, Am. J. Roentgenol. **34**: 724, 1935.
33. Zipkin, R.: On a Cystic Lung with Rhabdomyoma, Virchow's Arch. f. path. Anat. **187**: 244, 1907.
34. Smith, E. V., and Mills, R. G.: The Removal of a Large Dermoid Cyst from the Anterior Mediastinum, J. THORACIC SURG. **7**: 338, 1938.
35. Koboth, I.: Tumor-like Malformations of the Lung in Infants, Frankfurt. Ztschr. f. Path. **50**: 10, 1936.
36. Favre, M., Pallasse, E., Roubier, C., and Guichard, A.: Nodular Formations in the Lungs, J. de méd. de Lyon **16**: 783, 1935.

BECK OPERATION (HEART)

Report of Two Cases

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ALL members of this Association I am sure are thoroughly conversant with the exhaustive, meticulous, and painstaking experimental effort of Beck,[1] Mautz,[3] and their associates which has led to the development of the graft method of supplying additional blood to the myocardium. In addition, I am sure we all feel that probably no new surgical procedure of such vital importance to human life has been more carefully planned. The method is based on sound experimental effort, honest and accurate interpretation of phenomena observed, and has been carried out with complete precautions for avoiding grave sequelae, and for controlling such should they unfortunately occur.

It was because of my profound respect for and appreciation of the honesty, accuracy, and thoroughness of these men in their work that I undertook the operations herein reported.

I do not apologize for reporting only two cases because the Thoracic Association is the proper judicial body to adjudicate on the wisdom of the procedure, and all cases should be reported until every possible question in the selection of cases—the type of operation, the complications and after results—has been repeatedly studied.

All of us have long realized the sad, distressing, and hopeless relation of coronary disease to sudden death and the relentless course of the disease to its finale.

Those of us who have had experience in cardiac surgery, either for trauma or for inflammatory conditions, have felt that cardiac ischemia was a more common factor in cardiac distress than myocarditis.

The increasing incidence of coronary disease and our utter helplessness to check its persistent and all too rapid course have, I am sure, been a "*bête noire*" indeed to every member of this splendid Association. Approximately four and one-half years is the average expectation of life after the disease manifests itself. Unfortunately, it usually occurs in those who are most active and those driven on by ambition or the necessity to accomplish great things. Of course, as is to be expected, it attacks those who "burn the candle at both ends" either in productive effort or in purposeless excesses. The occasional patient who survives successive attacks of coronary thrombosis and becomes active again even after years of distress serves only to demonstrate the necessity of closer

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study of the means by which compensation occurs. That natural compensation in angina pectoris results from the association of pericarditis was an important observation, and Sternberg's[5] classical case of epistenocardica is an example of similar cases that we all have seen from time to time. Fairly sharp hemorrhage from the cut surface of pericardial adhesions that have been severed has been observed by all of us. These factors, added to the daring and original experimental work of Dr. Beck and co-workers, have led us to the application of the principle that, if additional blood could be supplied to the myocardium by any means without an overwhelming operative mortality, the procedure should be adopted in selected cases.

I propose to describe our second case first.

Patient No. 102651, a white male, farmer, aged 50 years, presented himself first for examination Dec. 14, 1936, complaining of:

1. "Recurring sickening pain, followed by a dull dead ache through the chest, caused by exertion, and disappearing with rest of three years' duration.

2. "For two years having severe periodic attacks after the least exertion or excitement with pain down the left arm, certain he was dying for some minutes, and obliged to remain in bed for as long as three weeks after such attack.

3. "Overloading the stomach ever so little at once caused a vague pain behind the breast bone."

Normal weight was 140 pounds. Weight at the time of examination was 133 pounds after weight loss for one year. The blood pressure varied from 136/84 to 145/112; the pulse was 80. The heart was enlarged a little with many extrasystoles and a mitral systolic murmur. There was no edema of the legs, and, on the whole, the heart was compensating fairly well.

Physical examination was essentially negative otherwise except for a mild infection in the tonsils and a slight dental infection. The urine was negative. The hemoglobin was 100 per cent, the white count, 7200, and the Wassermann test, negative.

A diagnosis of angina pectoris of a grave type was made. He was put at rest on a restricted diet with aminophyllin and elixir luminal and advised that operation would be necessary.

After a very bad winter, with constantly recurring attacks after the least effort, he returned to the Clinic May 1, 1937. In the meantime, he had lost some weight, and the attacks were occurring almost daily. He was entirely incapacitated for work or effort of any kind. The heart, however, was still compensating remarkably well.

The electrocardiograph showed T_1 negative, T_2 flat, T_3 slightly plus, the Q_3 present.

He had his mind firmly made up that surgery was his only hope. He was not the least apprehensive or worried about the operation itself.

He was given quinidine twenty-four hours prior to operation without any reaction to it, and on the evening prior to operation and the morning of the operation, the drug was repeated.

He was operated upon at 9 A.M. May 6, 1937, under local anesthesia associated with sufficient preoperative narcosis to allay all dread and fear of the procedure. We were prepared to start intratracheal anesthesia at once if required. A left unilateral transverse incision was made from the cartilage of the fifth rib to the nipple line. The fifth and sixth costal cartilages were resected, removing about one-half inch of each rib as well. A good size muscle flap was fashioned from the

pectoralis major, and the pericardium was opened widely close to the border of the sternum. The pericardium was tense. There were no adhesions within the sac and very little fluid. The myocardium was pale and avascular. There was no appreciable change in blood pressure until the epicardium had been thoroughly abraded with a burr. The systolic pressure dropped from 110 to 80 mm. of mercury but improved rapidly after ephedrine was administered. Six drams of ground bone was rubbed into the mediastinal fat, over the auricles, and about the site for attachment of the flap. The flap was split, the upper portion was applied to the left border of the heart, and the lower portion was carried in behind the right border and was sutured to the lateral flap of the pericardium. A small opening had been made in the pericardium laterally and posteriorly to allow drainage into the pleural cavity. The right or median pericardial flap was lightly apposed to the anterior surface of the flap with three or four interrupted sutures. The incision was closed firmly in layers without drainage. Just before closing the first layer completely, the lung was inflated as a precaution. Throughout the operation requiring 1 hour and 15 minutes the patient had no respiratory distress whatever, complained of no pain or anxiety during the manipulations and scarifying of the epicardium and pericardium; on completion of the operation, his pulse rate was 110, respirations 20, and blood pressure almost exactly what it had been prior to operation, 110/90.

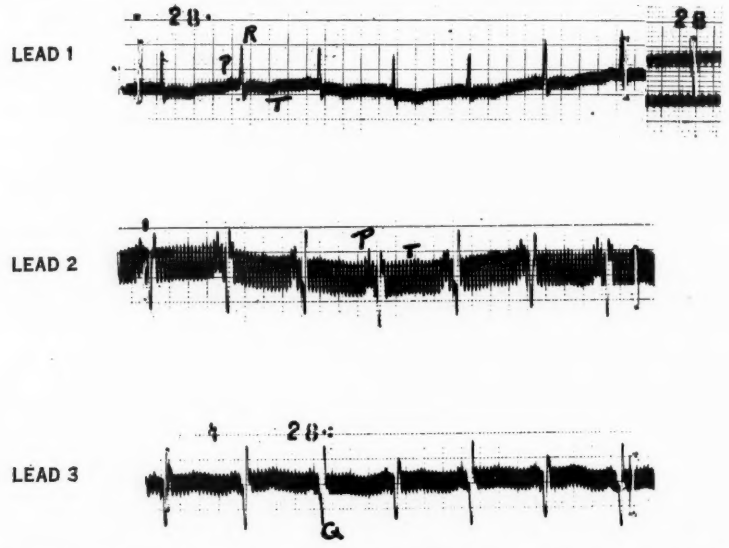

Fig. 1.—Case 102651. T_1 negative; T_2 flat; T_3 slightly plus; Q_3 present. Suggests an old coronary lesion. A Q_3 is present in a certain percentage of cases of angina.

After the wound was closed and hermetically sealed with a mastisol and gauze dressing, a needle was passed into the pleural cavity to withdraw air and to encourage further expansion of the lung should it be partially collapsed. On passing in the needle, I came direct on the lung and remarked that the lung was apparently in complete expansion. The needle punctured a vessel and was at once withdrawn. The patient was returned to his room. His condition was splendid. There was no cyanosis, no dyspnea, no precordial pain, and no more extrasystoles than there had been. All day his condition was good until about 5 P.M. when he became a little

restless, and although he quieted nicely after 1/6 gr. of morphia hypodermically, he did not seem to be quite as well as he had been during the day. However, his blood pressure had not changed, but his pulse was 130 and respiration 28. He rested comfortably all the evening until about 10 P.M. when he seemed a little more anxious than formerly; his pulse was somewhat weaker, but not more rapid. His color was good. His breathing seemed a little shallow. An aspirating needle was passed into the pleural cavity, and only about 30 c.c. of blood-stained serum could be withdrawn. However, at once the pulse regained its volume, and he was distinctly better generally. At midnight we gave him 900 c.c. of 5 per cent glucose in Ringer's solution intravenously. This did not bother him at all but did not materially strengthen the pulse. At 5 A.M. his pulse was 140 and was not of such good volume. We aspirated the chest again and withdrew 40 c.c. of light-colored bloodstained fluid. This again seemed to improve the volume of the pulse. We were certain that he could not be bleeding. His respirations were 28 to the minute. The heart was not fibrillating. His condition simulated somewhat that of patients I had seen with contralateral collapse in France during the War. However, he had no cyanosis and no apparent respiratory distress, and he resisted oxygen administration. He became somewhat irrational and restless. At 8 A.M. we gave him a small blood transfusion, 300 c.c. of blood, followed by 300 c.c. of normal saline solution by continuous drop method. His pulse beat at this time was 120 per minute and respirations 18 per minute. His temperature was never over 100° F. At 10 A.M. he died, twenty-six hours after operation. Throughout this time he did not complain of shortness of breath, was not cyanosed until just at the end, and had no cardiac distress whatever. There was no fibrillation of the pulse. His condition suggested that of hemorrhage, but we were certain that could not be. Examination of the chest through the wound after death revealed the latter to be firmly closed. The muscle flaps were already adherent to the myocardium. There was no fluid in the pericardium. On opening the pleura, the left lung was found to be in complete collapse except for a small portion of the upper lobe. There was not more than 5 c.c. of fluid in the pleural cavity. There had, of course, been no bleeding. We did not have permission to remove anything. I believe removal of the trachea and lung and inflation under water would have revealed perforation of a main bronchus by the aspirating needle at the conclusion of the operation, followed by massive pneumothorax. Although I have seen but one other case, that reported by Dr. Willus Lemon years ago, I am convinced that was what accounted for this unfortunate outcome. I should have suspected the condition. The lung should have been inflated by positive pressure, and maintained inflated, and the patient given sedatives to have kept him in comfort in the oxygen tent, and I feel certain he would have recovered. The facts that he had been having almost constant substernal distress prior to operation with daily attacks in which he felt certain he would die, that he stood the operative procedure entirely under local anesthesia without any distress whatever, and that for twenty-six hours postoperatively, despite his condition, he never once complained of his heart, suggest that there might have been some factor, perhaps merely the free opening of the pericardium, that accounted for the immediate relief of distress observed after this operation. It is noteworthy also that despite his restlessness, fibrillation of the heart did not occur.

I cannot account otherwise for death in this case, particularly since the lung was in total expansion when the aspirating needle was inserted. The needle was not passed more than 3 cm. until the lung was punctured and blood withdrawn in the needle.

This case is reported in some detail, as I believe it is much more important to report our failures than our successes.

The first case operated upon was a male, aged 50 years, a newspaper man. He was examined Dec. 1, 1936. Main complaint was "pain in the chest and shortness of breath on the least exertion for over a year."

He had had some distress over the cardiac area for three years, but he had his first severe attack in January, 1936. He was certain he was going to die. He was in bed three weeks, and "never recovered" from that attack. He had "been an invalid ever since." He was a well-nourished man, weighing 160 pounds, but was pale and of flabby musculature. He led an irregular life, kept late hours, smoked excessively (cigarettes), ate at all hours, and took liquor to excess. He took no exercise and did not believe in holidays.

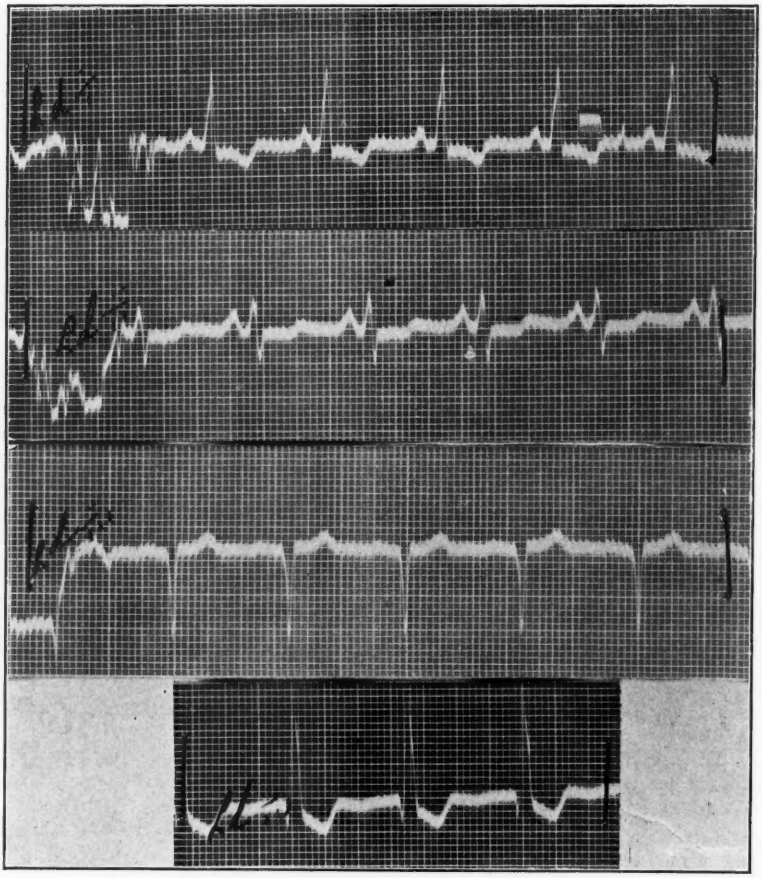

Fig. 2.—1. Negative T-wave in Lead I; 2. A low ST interval in Lead II; 3. Slight degree of slurring of the QRS wave in all leads, especially in Leads I and II; 4. Left axis deviation. The T-wave changes noted in this electrocardiogram are abnormal and indicative of myocardial change, probably of coronary origin.

His examination was essentially negative in every way except for enlargement of the heart II (on a scale of I to IV), a well-marked mitral systolic murmur, and considerable moisture and congestion at the base of both lungs. He had a typical cigarette cough and five teeth with some periapical involvement.

The blood pressure on repeated readings averaged 158/108. The pulse rate averaged 96 per minute. The urine and blood were normal. The Wassermann test was negative.

He had been on digitalis periodically for ten months.

An electrocardiogram showed marked myocardial damage, probably of coronary origin.

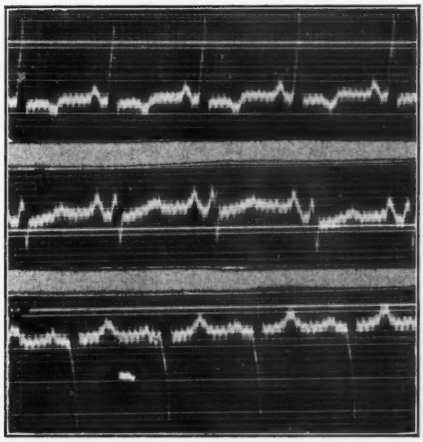

Fig. 3.—Electrocardiogram shows splitting of the QRS complex in all leads though there is no widening. The T-wave in Lead I is inverted and has a low take-off, and there is left axis deviation.

He was in the hospital several ten-day periods throughout December and January. He had frequent minor attacks and several rather severe coronary attacks while in bed, but refused to remain in the hospital. On Dec. 26, he had a very severe attack typical of coronary occlusion, and an electrocardiogram on Dec. 31 revealed marked myocardial damage. Complete rest in bed relieved him very little, and he had minor attacks almost daily. However, the teeth were extracted, and the moisture in his chest cleared up fairly well. We tried to persuade him to go to Dr. Beck in Cleveland for surgical treatment. However, in spite of rest in bed, his distress and recurring attacks persisted, and Feb. 4, 1937, under local anesthesia, we operated upon him. The operation was exactly that carried out in the former case. He had, however, well-marked adhesions from the pericardium to the lower portion of the heart. These were not interfered with, but it was not so easy to scarify the epicardium. He had more fat over the base of the heart, in the mediastinum over the pericardium. He stood the operation well, had very little change in blood pressure, and no respiratory or cardiac distress whatever at any time. He was wide awake and carried on a conversation throughout the procedure. The operation lasted one hour and thirty minutes. He had an entirely uneventful recovery and the morning of the second day stated that the sense of weight and pressure over the precordia that he had had for months had disappeared. He said he could breathe more easily. On the third and seventh days he had two very minor at-

tacks, of no consequence whatever, due to apprehension, and lasting only a few minutes. On the twenty-fourth day he had a similar slight attack. On the twelfth day we were greatly concerned when we found he had some deep suppuration in the incision. However, this rapidly responded to treatment and apparently did not affect the course of his recovery. He was up and about from the twenty-sixth day, but because of his habits of life, we persuaded him to remain in the hospital until April 21. He had, however, been going out daily to walk and ride in a car.

Three weeks later he returned to light duty, working half a day. His general condition was much improved, and he had no subsequent attacks.

On the evening of June 25, he was found dead in a hotel bedroom.

A partial examination was permitted. The incision was firmly healed. The flaps were firmly adherent to the heart, and well-marked blood vessels were present. There was evidence of old multiple infarcts in the myocardium and marked stenosis and obliteration of the coronary arteries and advanced aortitis. The left lung was in complete expansion. The stomach and duodenum contained alcohol, and there was a marked gastritis and duodenitis.

Investigation into the circumstances in connection with his death revealed that he had been drinking excessively for three weeks prior to his death. He had driven all over the country, one trip of 490 miles each way. He had been in the company of a woman throughout this time. They had consumed a tremendous quantity of liquor. He was smoking excessively and eating and sleeping at all hours. He had not complained of his heart to her, and in so far as she knows he died in his sleep. Several empty whiskey bottles scattered about the bedroom testified to the amount of liquor they had consumed in the last day or two prior to his death. The three weeks' debauch testifies to the extraordinary degree of benefit he must have received from the operation. The degree of gastritis and duodenitis that he had was in itself sufficient to kill a man who had never had any cardiac problem.

These two cases represent patients practically completely incapacitated by coronary disease with a marked fear syndrome equally as distressing as the attack itself. Having substernal distress almost constantly, shortness of breath, a constant sense of oppression in the chest, and almost daily acute attacks of greater or less degree, they both stood the operative procedure without the least immediate ill effect of any kind.

I believe we must accept it as a fact that the operation itself is a relatively safe procedure and does not entail even an alarming mortality rate. The extraordinary group reported by Beck[6] of seventeen consecutive patients operated upon without a death surely bears out this statement.

We must also realize that cardiac ischemia is the main cause of the distress, and that there is now irrefutable evidence that the muscle flap and the irritative process set up by the use of bone dust or aleuronat cause blood vessels to develop which not only convey blood to the myocardium, but directly anastomose with the branches of the coronary tree.

At the end of a week, new vessels can be demonstrated in the experimental animal, and at the end of three weeks, injection with India ink or barium emulsion shows direct anastomosis to the coronary vessels.

A sufficient number of patients have been successfully operated upon, and with such a degree of relief as to warrant application of the operation to a larger percentage of patients afflicted with this otherwise hopeless condition.

Whether the operation now employed by Beck or that of cardio-omentopexy so successfully carried out by O'Shaughnessy[7] and his associates is the operation of choice remains to be established. Personally, I believe the muscle flap should be more efficient and is a simpler procedure.

The safety and wisdom of this operation and the application of it before patients are in extremis is a duty we of the Thoracic Association must assume if a higher percentage of patients are to be referred earlier for operative relief. The profession generally must be made to realize that:

1. Ischemia plays the dominant part in the majority of cases formerly diagnosed as "myocardial degeneration" or "chronic myocarditis."

2. The warning symptoms are shortness of breath on exertion or emotional effort and a feeling of oppression in the chest.

3. An extreme degree of cardiac ischemia may exist without causing pain at all.

4. Coronary thrombosis and the acute pain of angina pectoris are, as a rule, late symptoms of long standing, progressive ischemia.

5. Finally, while the operation should be employed for a high percentage of patients suffering from angina pectoris and coronary disease, every possible precaution must be taken at the operating table and postoperatively to ensure the successful carrying out of the procedure. The success of Beck and Mautz in avoiding auricular and ventricular fibrillation and in overcoming it should it occur, must be thoroughly understood, and the solution and electrodes must be ready for immediate use.

A select anesthesia is most important, and the anesthetist must be prepared to inflate the lung if necessary.

The patient should be given the benefit of the doubt, should be returned to an oxygen tent, and maintained in it in comfort until entirely convalescent.

While I believe it is a wise precaution to provide for drainage from the pericardium into the pleural cavity, I feel it is important not to open the pericardium too widely for that purpose.

Every step in the operative procedure should be rehearsed, and every member of the operating team must know his or her duties and act quickly, methodically, and without a moment's delay.

Beck and his associates have, I believe, made a most momentous, heroic and life-saving contribution to the unfortunate victims of an otherwise

hopeless and rapidly fatal disease. I am sure we hail with delight this great triumph of one of our members and likewise thrill to the successful and thorough effort of O'Shaughnessy and his associates along the same lines in London.

REFERENCES

1. Beck, C. S.: The Development of a New Blood Supply to the Heart by Operation, Ann. Surg. **102**: 801, 1935.
2. Beck, C. S.: Further Data on the Establishment of a New Blood Supply to the Heart by Operation, J. THORACIC SURG. **5**: 604, 1936.
3. Mautz, Frederick R.: Reduction of Cardiac Irritability by the Epicardial and Systemic Administration of Drugs as a Protection in Cardiac Surgery, J. THORACIC SURG. **5**: 612, 1936.
4. Mautz, Frederick R.: Resuscitation of the Heart From Ventricular Fibrillation With Drugs Combined With Electric Shock, Proc. Soc. Exper. Biol. & Med. **36**: 634, 1937.
5. Sternberg, M.: Wien. med. Wchnschr. **60**: 14, 1910.
6. Beck, C. S., and Mautz, F. R.: The Control of the Heart by the Surgeon, Ann. Surg. **106**: 525, 1937.
7. Davies, Daniel T., Mansel, H. E., O'Shaughnessy, Lawrence, and Viscount Dawson of Penn: Surgical Treatment of Angina Pectoris and Allied Conditions, Lancet **1**: 1-10 and 76-82, 1938.

TREATMENT OF PULMONARY TUBERCULOSIS BY TEMPORARY ELIMINATION OF A NUMBER OF INTERCOSTAL NERVES

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FUNCTIONAL REST ESSENTIAL IN THE MANAGEMENT OF TUBERCULOSIS

FUNCTIONAL rest is the underlying condition for success in the treatment of all forms of tuberculosis, skeletal as well as pulmonary. Even the well-established success of collapse therapy in pulmonary tuberculosis by pneumothorax or thoracoplasty is due in part to the functional rest it secures the affected lung. The more perfect the rest, the better the result by either of these procedures. As to the phrenic nerve operations, the like principle obtains, and, if the lung is free from adhesions, the collapse will be distributed evenly throughout the organ, no matter whether the approach is through an intercostal space or by way of the diaphragm. But freedom from adhesions is not the rule; therefore, the effect of phrenic nerve paralysis is exerted mainly on the lower part of the lung, and the patient instinctively compensates the loss by a greater degree of thoracic expansion. This would be the rational procedure in cases where the tuberculous lesion is in the lower half of the lung while the upper part is in a fairly good condition. But, most frequently, the condition is exactly the reverse. In those cases it would be more advantageous to provide functional rest to the affected upper part and to leave intact the rhythmical descent and ascent of the diaphragm, a motion which, by exerting a gentle massage on the underlying abdominal organs, aids the circulation of blood and lymph in those organs. Its descent on the liver may be likened to the pressure of the hand on a sponge filled with fluid; its ascent, by releasing the pressure, helps to refill the organ. The intermittent pressure of the diaphragm on the stomach and colon aids peristalsis in those organs.

DIAPHRAGMATIC VS. THORACIC RESPIRATION

The desirability of encouraging diaphragmatic breathing and keeping the chest comparatively motionless was stressed in 1922 by S. Adolphus Knopf, the nestor of tuberculosis specialists, who took great pains instructing his patients in the mode of breathing and saw good results. This method necessitates much supervision, as the patients are inclined to be negligent, and during sleep, respiratory control is impossible.

Read (by title) before The Twenty-First Annual Meeting of the American Association for Thoracic Surgery at Atlanta, Ga., April 4, 5, 6, 1938.

*This article is being published posthumously and without the benefit of a revision of the proof by the author. Dr. Torek died Sept. 19, 1938.

HISTORY OF NERVE RESECTION TO ELIMINATE INTERCOSTAL NERVES

It is but natural that attempts were made to bring about diaphragmatic instead of thoracic breathing by means independent of the patient's cooperation. Surgical means were devised to eliminate the function of the intercostal nerves which control the motion of the ribs. Schepelmann, in 1913, was the first to experiment on animals in this line. He resected all twelve intercostal nerves to bring about the collapse of one lung. In 1914, Friedrich resected all twelve intercostal nerves on one side in a human being and in another case resected five ribs, third to seventh, and four intercostal nerves, fourth to seventh. In the same year, Warstat operated in two cases, in one of which he resected eleven intercostal nerves, in the other, four nerves in combination with rib resections. He reported improvement in both cases. In 1929, John Alexander published an article, "Multiple Intercostal Neurectomy," reporting satisfactory results. He operated in six cases, resecting ten nerves in each case, second to eleventh.

ALCOHOL INJECTION

In 1926 Morelli advocated placing one side at rest either by resection of the intercostal nerves or by injection of alcohol into them. In the same year Leotta, of Palermo, became interested in this subject, at first resecting seven intercostal nerves. In 1928 he gave up this method in favor of alcohol injection.

BILATERAL INJECTION OF ALCOHOL

The most important change was made by Leotta in 1931, when he began to practice injection of alcohol into four or five nerves on both sides. I consider the bilateral injection to be of great significance, not only because it is rare for one lung to be entirely healthy, but particularly because, in the unilateral procedures, the collapse of the diseased lung may actually favor propagation of the disease to the opposite side or, if that side is already involved, may aggravate the process by stirring up foci which theretofore had been inactive. This possibility is well known to those who have experience with pneumothorax or thoracoplasty and causes them much concern as to the behavior of the other lung. The danger of reactivating a focus in the other lung is largely due to the displacement of the mediastinum toward that side with its unfavorable influence on circulation, to which is added a restriction of the mobility of that lung, both inspiratory and expiratory. Displacement of the mediastinum, however, can be avoided with certainty by injecting the alcohol bilaterally. In this way the functional rest is properly balanced, and the patient adapts himself to the changed respiratory mechanism much more easily than after a unilateral intervention. The results of bilateral paralysis have proved to be superior to

those of the unilateral procedure. The paralysis lasts two or three months, after which thoracic respiration is slowly reestablished. The injection is repeated after about three or four months, depending on the condition of the patient. According to Leotta it should never be stopped in less than two years.

TECHNIQUE

At about 4 cm. from the spinous processes of the vertebrae, on both sides, the injections are made beneath the third, fourth, fifth, and sixth ribs, and in exceptional cases also the seventh. At the stated distance from the midline, the nerves and blood vessels are located in a roughly triangular space, the costopleural triangle, which is filled with loose connective tissue. This triangle has its apex below. The base corresponds to the lower border and part of the anterior surface of the rib above the intercostal space. The anterior wall is the pleura, the posterior wall is the posterior intercostal ligament. The alcohol injection is made into this triangle. It is not imperative to inject into the nerve, but the point of the needle must be within the said space. The alcohol injection is preceded by novocain. As 2 c.c. of alcohol is needed for the injection, a large amount of weak

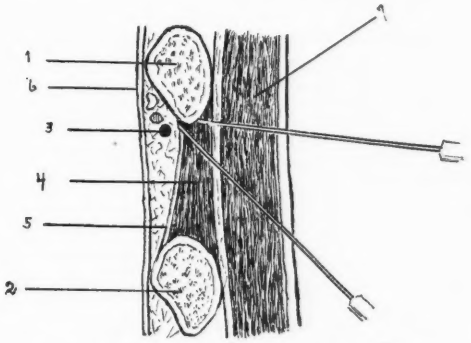

Fig. 1.—Schematic drawing of a section of the third and fourth ribs at a distance of 4 cm. from the midline. The external intercostal muscle is attached to the upper rib at the outer lip of its groove, and, as at this location there is no internal intercostal muscle, a small triangular space is established, filled with loose connective tissue through which the nerve and vessels run. The needle is shown in two positions; the upper for finding the border of the rib; the lower in the oblique, slightly advanced position, retaining its contact with the bone, ready for the injection. 1, Third rib; 2, fourth rib; 3, nerve; 4, external intercostal muscle; 5, posterior intercostal ligament; 6, pleura; 7, dorsal muscles.

novocain should be avoided, because the total amount might distend the triangle to such an extent as to lift the pleura from the adjacent ribs. It is therefore better to inject a smaller, more concentrated amount, say 0.5 c.c. of a 4 per cent solution of novocain. As to posture, I prefer having the patient lying on his side rather than sitting up, in consideration of the patient's weakness. The hand hangs down over the edge of the table, thus conveniently flattening out the dorsal muscles. Materials needed are: novocain 0.5 per cent, novocain 4 per cent, alcohol 95 per cent, a small needle for making the skin wheal, a 2-inch needle for injection into the costopleural triangle. This needle should be somewhat stronger than the first to permit changing its direction without danger of breaking it. Also needed are three syringes, one for novocain 0.5 per cent, one for novocain 4 per cent, one for the alcohol injection, the latter to hold 2 c.c. The

procedure, then, is as follows: After locating the spinous process of the seventh cervical vertebra, the vertebra prominens which is always easily felt, find the end of the second dorsal spinous process. This is in line with the lower border of the third rib. About 4 cm. from that spinous process a skin wheal is made with 0.5 per cent novocain. Through this wheal a needle, about 2 inches long, is inserted until contact with the third rib is felt. To forestall pain as well as possible, 0.5 per cent novocain had better be injected as the needle moves down through the muscles to the rib. With the needle the operator then searches for the lower border of the rib and keeps the needle in contact with it. As soon as the needle passes this border it enters the costopleural triangle. To make doubly sure that the point is in this triangle, the syringe is depressed, so that the point of the needle is directed slightly upward, and it is advanced a few millimeters farther (see illustration), the needle always remaining in contact with the lower border of the rib. This, of course, brings the needle closer to the pleura, but, if advanced no farther than stated, it will not penetrate it. Now 0.5 c.c. of a 4 per cent solution of novocain is injected into the triangular space. After the lapse of a few minutes there follows the slow injection, through the same needle, of 2 c.c. of 95 per cent alcohol. This amount should not be exceeded in order to avoid the possibility of lifting the pleura off the ribs and scattering the fluid. The patient is then turned on the other side and the corresponding nerve is similarly treated. Of course, one might prefer injecting through all four intercostal spaces on one side before turning the patient over for the other four injections. But the patient will appreciate the more frequent change in position, and the mediastinum will be better steadied by making the second injection on the opposite side. Furthermore, if there are signs of weakness after a few injections have been made, it might be considered wiser to stop before completing all the eight injections. In that case the mediastinum will remain fairly well balanced at any time on interruption of the procedure if the injections have been made alternately on the right and left sides. As I have mentioned, it is not necessary to inject directly into the nerve. The important thing is to keep the point of the needle close to the lower border of the rib to make sure it is in the costopleural triangle. Following this technique, the third intercostal nerve is more likely to be met by the needle than any of the others, as it lies in front of the lower part of the third rib, whereas the fourth is just below the rib and the fifth and sixth are still lower. Some pain, experienced at the end of the injection, soon passes off. If the needle has touched the nerve, the patient feels some pain at the sternum. If alcohol is injected into the nerve, he complains of a sharp sternal pain of short duration. Should the needle impinge on the pleura, it is likely to cause a tendency to cough. In that case the needle is withdrawn a few millimeters before injecting. In some cases a moderate degree of pain may last a few days. In cases of dyspnea or in severely sick patients it may be well to inject only the two third nerves and wait a few days before proceeding further.

HEMOPTYSIS

In cases of hemoptysis, improvement is immediate, even if only two nerves are injected. There are cases of hemoptysis in which neither thoracoplasty, pneumothorax, nor unilateral alcoholization has succeeded in stopping the bleeding. These are believed to be due to ulcerations located centrally, near the mediastinum, which remain active on account of mediastinal fluttering. Bilateral alcoholization avoids mediastinal fluttering and, therefore, puts even those ulcers at rest, as it abolishes,

or at least reduces, that particular kind of traumatism coincident with the cough, both on inspiration and expiration, which, after any of the unilateral procedures, is apt to be accompanied by a rather violent to-and-fro motion of the mediastinum. If a pneumothorax already exists on one side, the addition of one on the other side would have the same advantage and might perhaps be preferred, unless the establishment of pneumothorax is either impossible or is rendered useless for the purpose of equalizing the pressure owing to the attachment of a cavity to the pleura.

POSTOPERATIVE COURSE

The immediate result of alcoholization of the four pairs of intercostal nerves is a decided diminution of the respiratory excursions of the chest. The loss can be seen by inspection and still better by a determination of the vital capacity. Toward the end of the second month the nerves begin to regenerate. We then find a certain degree of chest motion and an increase of vital capacity. Beginning three or four months after the first series of injections, the procedure is repeated at regular intervals and is discontinued only if there seems to be a clinical cure, but never before the lapse of two years. Improvement in the general condition is noticeable in the second or third month, followed by a diminution of cough and expectoration, disappearance of râles and of dullness on percussion. A corresponding improvement is seen in the roentgenograms. Finally there is a disappearance of tubercle bacilli in the sputum. These observations as to the clinical course are taken from Leotta, as my own experience is too limited to draw general conclusions, but I do want to mention that I had a case in which improvement was immediate. This was a fibrosclerotic case. Cough and expectoration were reduced to one-third of the previous amount on the very next day after the injection treatment, and the general condition was likewise improved. Leotta's follow-up shows very favorable results, including clinical cures of long duration.

In favor of this method, which brings about functional rest, one can positively say that it is absolutely free from danger, that the pleura is excluded from participation in the treatment, and that, when the clinical cure is complete, there remains no anatomical deformity. As a general rule it should not be used in combination with the surgical collapse methods. Under no circumstances should it ever be combined with a phrenic nerve operation.

INDICATIONS FOR THE EMPLOYMENT OF THIS METHOD

Among the practically unlimited indications for this method of treatment, the most outstanding one, to my mind, is found in cases in which it is impossible to establish a pneumothorax on account of firm pleural adhesions, a condition found most frequently in the fibrosclerotic forms.

In those fibrosclerotic cases, Leotta claims clinical cure in 100 per cent of the patients. Secondly, the method is indicated in severe and obstinate hemoptysis. Here the bilateral alcohol injection is practically infallible. In these cases, if the indication is urgent, the alcoholization should be restricted to the two third nerves, or possibly the third and fourth. It seems to me the method may be of value in the management of thoracic traumatism and lung abscess. Finally, this method deserves consideration in two widely different conditions: first, the early cases in which one cannot make up his mind whether a pneumothorax is necessary; and second, in cases so severely sick that one would not dare to advise any of the operative procedures. In many of these last-mentioned cases improvement, both general and local, has been seen.

REFERENCES

Knopf, S. A.: New York M. J. **116**: 65, 1922.
Schepelmann, Emil: Arch. f. klin. Chir., March, 1913.
Friedrich, L. P.: Verhandl. d. deutsch. Gesellsch. f. Chir., 1914.
Warstat: Deutsche Ztschr. f. Chir., 1917.
Alexander, John: Multiple Intercostal Neurectomy, Am. Rev. Tuberc. **20**: 637, 1929.
Morelli: Soc. Italiana di Chir., 1925.
Leotta, Nicola: Academia medica di Roma, 1926, 1928. Congresso Nazionale Antitubercolare, Palermo, 1929. Rivista Sanitaria Siciliana, 1929, 1931, 1932. Lotta contro la tuberculosi, 1932, 1933.

PATIENT SUPPORT FOR THORACOPLASTIES AND OTHER THORACIC OPERATIONS

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IN DOING surgical operations, the position of the patient is extremely important. The speed of the surgeon and the ease of operating is affected markedly by the patient's being in the proper position. For thoracoplasties, it is required that the patient be placed in the side-lying position, and this, more than the other positions, is difficult to maintain. The heavy retraction of the scapula during the operation tends to displace the patient from the original towards the prone position. The time-used sandbags are generally employed to hold the patient in the proper position, and it has been noted that there is always a change in position during the operation. In many cases the position was almost face down on top of the anterior sandbag. This delays the later part of the operation and makes the work very difficult. It has not been possible to prevent this change in position with various appliances while using the sandbags. It became very evident that some apparatus was needed to replace the old sandbag and prevent this undesirable and needless change in position.

The patient support is such an apparatus. It provides a rigid unyielding support, allowing the patient to be properly placed on the operating table and assuring the same position throughout the operation. It is composed of a posterior and an anterior support.

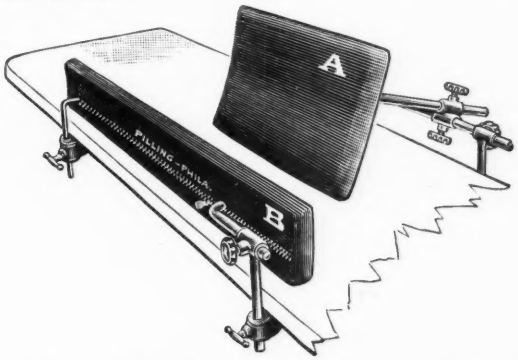

Fig. 1.—Howard thoracoplasty table support. *A*, Anterior support; *B*, posterior support.

The posterior support is 30 inches long, 4 inches wide and 1½ inches thick. It is attached to the operating table by two rods which fit into the arm and leg rest sockets or into two rail couplers. One rod is adjustable for distance between the rods so the support can be adapted to the arm and leg rest sockets on any standard table. When attached, the support fits snugly against the edge of the table and provides a low side board at the back of the patient. This permits placing him at the edge of the table nearest the surgeon without danger of his slipping off. The support is not wide enough to interfere with the operation.

From the American Legion Hospital, Battle Creek, Mich.

The anterior support is a plate 20 inches long and 10 inches high, molded to fit the anterior surface of the thorax. It is equipped with two rods, mounted firmly above the vertical center near each end. These are attached to an accessory rail by couplers, which permit the support to be moved from that side of the table across to within 6 inches of the posterior support and also lengthwise on the table from the head to below the middle. The two couplers are provided with set screws, which, when tightened, fix the support in any position. Both supports are cushioned with sponge-rubber pads and covered with rubberized fabric, all of which are removable. The accessory rail is attached to the table by two coupler rods, which fit into the arm and leg rest sockets or into the regular rail couplers. By raising or lowering this accessory rail the vertical angle of the anterior support can be changed; by reversing the position of the chest plate the vertical angle can still further be changed. Through the various adjustments, the support can be used successfully with tall or short, stout or thin patients with any form of thorax. The patient can be placed with the shoulders at any angle from true lateral to almost prone; the support can be adjusted and set to hold this position, and, with the use of the regular restraining straps, it is not possible for the patient to change his position through struggling under the anesthetic or voluntary effort. Full retraction may be used without danger of disturbing the patient's position. Adjustments for any desired change in position can be easily made during the progress of the operation.

The patient support is a practical apparatus for use in all forms of operations in which the side-lying position is used. It replaces the old sandbags and eliminates the disadvantages of the change in position after the operation has been started.

The support has been used in the American Legion Hospital for five years with perfect satisfaction.

PARTIAL THORACOPLASTY (WITH EXTRAFASCIAL APICOLYSIS) AND CONTRALATERAL OLEOTHORAX

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THE use of partial thoracoplasty, combined with extrafascial apicolysis, has enabled the thoracic surgeon to widen his indications for the treatment of pulmonary tuberculosis. When paravertebral, extrapleural thoracoplasty was the accepted method for surgical collapse therapy, it was possible to undertake this procedure only in strictly unilateral lesions. This operation usually entailed the resection of parts of all the ribs over the involved lung, and, if the other lung did not contain sufficient normal pulmonary tissue, marked embarrassment of respiration would occur, with activation of the process existing in the contralateral lung.

When the lesion which is to be collapsed is situated in the upper part of the lung, the remainder of the lung (especially the voluminous lower lobe) may be preserved by employing partial thoracoplasty with extrafascial apicolysis. In this way, many patients with bilateral disease processes, who were formerly denied the benefits of thoracoplastic procedures, may now be subjected to operation.

The literature on the surgical treatment of pulmonary tuberculosis is evidence of the broadening indications for therapy in bilateral disease. The successful completion of bilateral thoracoplasties and all types of bilateral therapy, too numerous to mention, have been reported. The most popular form of bilateral surgical therapy is a partial thoracoplasty on the more diseased side, combined with pneumothorax over the contralateral lung. This pneumothorax may be marginal to afford relaxation for the entire lung or it may be of selective type over a localized diseased area.

Oleothorax has been advocated for sterilization of tuberculous empyemas and for compression of pulmonary areas, but its most ideal indication is for the maintenance of a successful selective collapse when the pneumothorax must be abandoned. An obliterating pleuritis is frequently the reason for inability to preserve an effective pneumothorax. When the collapse has been maintained for only a short period of time, every means must be used to continue it.

The question of voluntary abandonment of artificial pneumothorax in unilateral disease is still a subject for considerable disagreement among

From the Surgical Division, Montefiore Hospital, Dr. A. A. Berg, Chief of Division; and the Tuberculosis Division, Montefiore Hospital, Dr. Harry Wessler, Chief of Division.

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phthisiologists. It is therefore evident that in a patient with bilateral disease, the pneumothorax must be maintained for a longer time than would ordinarily suffice for unilateral disease, especially when an extensive contralateral rib resection is contemplated.

Oleothorax is not used simply for maintenance of a selective pneumothorax which is being obliterated by a pleuritis. It has some distinct advantages which suggest it as a collapse method of choice during the performance of a contralateral thoracoplasty.

Coryllos and Ornstein,[1] in reporting on the surgical therapy of a large series of cases of bilateral cavernous pulmonary tuberculosis, include eighty-one cases in which thoracoplasty was performed in the presence of a contralateral pneumothorax. They encountered twenty-two instances (in sixteen cases) of spontaneous pneumothorax, superimposed upon the contralateral pneumothorax. Four of these patients died.

The presence of oil in the pleural cavity would tend to lessen the chances for spontaneous pneumothorax. The oil is subject to less variations in pressure and exerts a more constant pressure upon the visceral pleural surface. Where oil is not used under high tension, but only as a maintenance oleothorax, the incidence of perforations into the bronchial system is small.

The use of any measure which will avoid respiratory embarrassment is necessarily of great importance in bilateral collapse therapy. We are dealing with patients with low vital capacity who are to be subjected to a thoracoplasty of major proportions. The oil will diminish the amount of respiratory difficulty both during anesthesia and postoperatively because of its tendency to fix the mediastinum and intrathoracic organs.

One possible disadvantage to the use of oil is that, after it has been present for a considerable length of time, it causes a thickening of the visceral pleura with some fibrosis in the adjacent pulmonary tissues. This would tend to prevent re-expansion of the lung at a later date. When a permanent collapse on one side, by means of thoracoplasty, is to be the end result, it is desirous to eventually regain as much respiratory surface as possible in the other lung.

Although the maintenance of bilateral pneumothoraces with a vital capacity as low as 500 c.c. has been reported, Jessen[2] correctly states that, in bilateral surgical therapy, the vital capacity should never be lowered below 40 per cent of normal or approximately 1,200 c.c. There is no value in arresting the patient's tuberculosis if he is to be left with an invaliding respiratory mechanism. And it must be remembered that while pneumothorax is temporary, thoracoplasty is permanent.

If the patient is dyspneic following thoracoplasty and it is felt that the oleothorax will prevent a later re-expansion of the healed contralateral lung, the oil may be removed and pneumothorax substituted. The presence of oil for only a short period of time will not cause sufficient

pleural thickening to prevent subsequent re-expansion. If, on the other hand, there is no respiratory difficulty after the patient has recovered from the operative procedure, the oleothorax can be maintained until it is decided that the collapse may be abandoned.

In cases of the two patients whose histories are presented, oleothorax was used as a procedure of choice in one and because of an obliterating pleuritis in the other. Both patients withstood the operation remarkably well, despite a very low vital capacity. The end result in one was excellent. The other refused an anterior costectomy and therefore still has a small patent cavity.

CASE 1.—C. H., No. 27788, a white female, married, age 21 years, was admitted to Montefiore Hospital Jan. 29, 1936. Her history dated back to 1928, at which time she had a bilateral pneumonia with a dry pleurisy. She was well until 1933, when she caught cold, began to streak and cough. An x-ray showed a cavity in the right lung with some infiltrations on the left side. She was admitted to Bedford Sanatorium in October, 1933, where artificial pneumothorax was induced on the right side but discontinued four weeks later because of its ineffectiveness. Her sputum was consistently positive. She returned home in September, 1934, and entered Bellevue Hospital in 1935. While there, bilateral artificial pneumothorax was induced. She was transferred to Seaview Hospital in January, 1935, where the pneumothorax on the right was discontinued because it was considered ineffectual. Intrapleural pneumolysis was done on the left side with an effective collapse of the left lung and a closure of a cavity which had been present. Patient left Seaview in September, 1935, and gained 9½ pounds in weight. The pneumothorax on the left side was continued at home and she entered Montefiore Hospital, having been advised to have a thoracoplasty on the right side.

Physical examination revealed a well-developed and well-nourished white female, 5 feet 4 inches tall, and weighing 110½ pounds. There were physical signs of a cavity in the right upper lobe and a pneumothorax over the left upper lobe.

X-ray examination revealed an extensive involvement of the right upper lobe, with a cavity measuring about 1½ inches in diameter. It showed a distinct fluid level. Another smaller cavity was seen just above, and an occasional tubercle in the right lower lobe. On the left side, there was a pneumothorax. The upper lobe was almost completely collapsed and the lower lobe showed a partial collapse of its upper portion.

Sputum was positive on numerous occasions. Hemoglobin was 65 per cent; R.B.C., 3,600,000; W.B.C., 9,400 with 68 per cent polymorphonuclears. Circulation time was 13½ seconds on the left, and venous pressure, 12 cm. Sedimentation rate varied from 19 to 26 in one hour. Her general condition improved, and in July, 1936, hemoglobin was 82 per cent, R.B.C. 4,600,000. Urine was negative.

The lower lobe on the left side was allowed to re-expand, and on May 16, 1936, x-ray showed that the pneumothorax on the left side was somewhat smaller than on previous examination. There had been a slight reexpansion of the left upper lobe. No cavity could be seen in the left lung. A small amount of fluid was seen in the pleural cavity at the base of the pneumothorax area. On the right side, the cavity in the upper lobe was about the same size and showed a fluid level. The vital capacity was 1,150 in February, 1936; 1,000 in April, 1936; and 1,000 in October, 1936. Left oleothorax was induced in June, 1936, and gradually increasing amounts of sterile mineral oil were introduced until the oil had completely replaced the air in the pleural cavity.

Bronchography, with the injection of lipiodol, in October, 1936, showed that there was a mild ectasia in the apical and paravertebral branch bronchi of the right upper lobe with terminal sacculation. The horizontal branch of the right upper lobe bronchus supplied the area of cavitation, but no lipiodol was seen to enter the cavity. Because of mild gastrointestinal symptoms, a gastrointestinal series was done which showed delayed gastric emptying and a moderate colitis of the distal colon but no x-ray evidence of gastrointestinal tuberculosis.

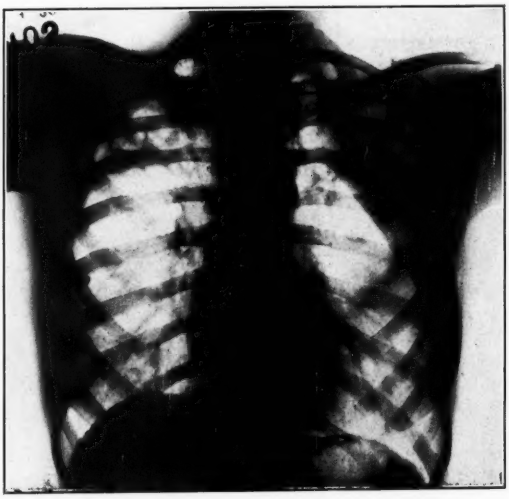

Fig. 1.—Case 1, C. H., No. 27788. Before thoracoplasty.

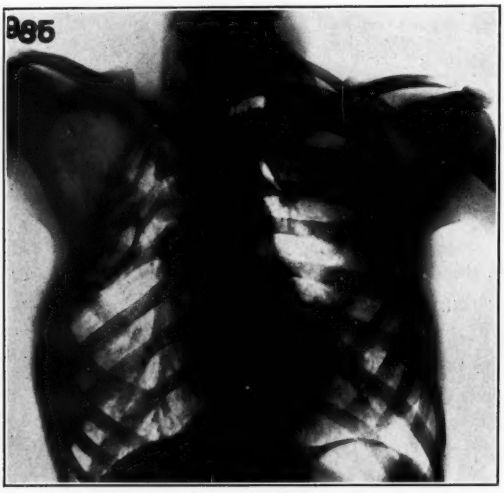

Fig. 2.—Case 1, C. H., No. 27788. After thoracoplasty.

Dec. 7, 1936, a first stage thoracoplasty with subperiosteal resection of the entire first rib and most of the second and third ribs with partial extrafascial apicolysis was performed. Anesthesia used was nitrous oxide and oxygen. The lung was found hard and fibrotic and firmly attached to the mediastinum and the brachial plexus and subclavian vessels. The lung was freed as much as possible, using the extrafascial method of Semb. Closure was made in layers, with one tube drain to the subscapular space.

Postoperative reaction was mild; her temperature reached 103° F. on the third postoperative day and then returned to normal on the fifth day. Tube was removed gradually. The remainder of the wound healed by primary union and the patient made a very satisfactory recovery.

Jan. 16, 1937, the second stage thoracoplasty, with subperiosteal resection of the fourth, fifth, and sixth ribs and resection of part of the anterior stump of the third rib, was performed. Anesthesia: nitrous oxide and oxygen. Usual subperiosteal resection of fourth and fifth ribs. Part of the anterior stump of the third rib was also resected, and the upper part of the lung was freed considerably by this procedure. The patient's condition remained excellent, and because the lung was so well fixed posteriorly, a small portion of the sixth rib was resected close to the spine. This permitted considerably more collapse. Wound closed in layers, with one rubber tube drain. Patient made a very rapid and satisfactory convalescence after the second stage. Wound healed by primary union.

X-ray, postoperatively, showed that the cavity originally present in the right upper lobe was diminished in size but still patent. Consequently, an anterior costectomy was indicated. Patient refused operation and was discharged March 14, 1937. She was readmitted to the hospital on July 22, 1937, with a history of having had a number of attacks of malaise and slight temperature while at home. Sputum remained positive. X-ray showed practically no change from that on discharge. She stated that she expectorated a small amount of oil on two occasions. She had lost 5 pounds in weight. A specimen of oil was aspirated for examination. No evidence of infection or a bronchial fistula was found. Her vital capacity was 1,000 c.c. Her condition has remained stationary up to March, 1938, and she refuses any further operative therapy.

CASE 2.—R. P., No. 79810, a white female, age 28 years, was admitted to Montefiore Hospital Nov. 14, 1936, with a history of having had pulmonary tuberculosis since December, 1934. She remained at home under bed rest until June, 1935, and then went to the country, where she became worse and lost weight. Pneumothorax was started on the left side in September, 1935. Since then, there has been a slight improvement in symptoms and she has gained 3½ pounds in weight. The past history and family history were negative.

Physical examination revealed a fairly well-developed and nourished young woman, pulse 116, blood pressure 115/85, respiration 26. Examination was negative except for the lungs, which presented the physical signs of a pneumothorax on the left side and a cavity in the right upper lobe. Sedimentation rate on numerous occasions averaged 27 mm. in one hour. Hemoglobin, on admission, was 75 per cent; R.B.C., 4,100,000; W.B.C., 11,000; 76 per cent polymorphonuclears. Wassermann test was negative.

Pneumothorax was induced on the right in December, 1935, and it was decided to maintain the pneumothorax on the left for a further period of observation. If it did not become effectual, it was to be discontinued. A spontaneous pneumothorax on the left, in December, 1935, with an accumulation of a small amount of pleural fluid, which was always negative for bacteria on smear and culture, was the indication for abandonment of the left pneumothorax. By April, 1936, the left lung had

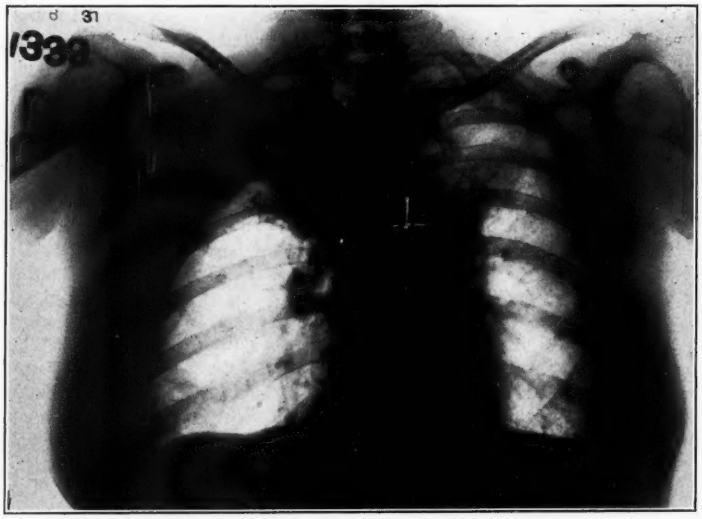

Fig. 3.—Case 2, R. P., No. 79810. Before thoracoplasty.

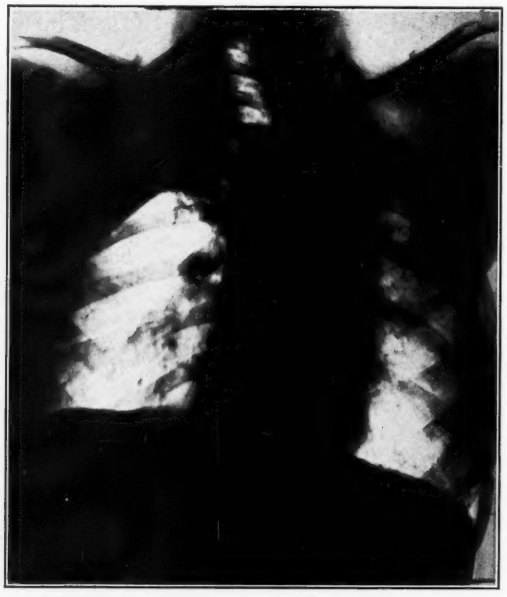

Fig. 4.—Case 2, R. P., No. 79810. After thoracoplasty.

completely re-expanded. The pneumothorax on the right side had been effectual in closing the cavity in the right upper lobe. In July, 1936, there was a tendency towards an obliterative pleuritis, and it was decided to preserve collapse by means of oleothorax. This was begun Sept. 22, 1936. Her vital capacity at this time was 1,400 c.c. The introduction of oil was accompanied by a febrile reaction and pleural effusion; therefore, the oil and fluid were aspirated. After the temperature returned to normal, it was decided again to attempt to institute oleothorax. This was now performed successfully, with no untoward reactions, and when the oleothorax had become stabilized, a thoracoplasty over the left upper lobe was performed on March 25, 1937, with resection of entire ribs one, two, and three, and extrafascial apicolysis. Anesthesia used was nitrous oxide and oxygen. After the usual subperiosteal rib resection, the lung was found to be hard, firm and markedly thickened, and adherent to the neurovascular bundle and mediastinum. An extrafascial apicolysis was then performed, with separation by blunt dissection over the entire apex of the lung, as well as on the lateral, anterior, and mediastinal surfaces. On completion of the apicolysis, the lung was at the level of the fourth rib. Postoperatively, there was a mild wound infection which was drained and which cleared up without further complications.

Second stage thoracoplasty was performed on May 14, 1937. The old scar was excised, scapula retracted, fourth and fifth ribs resected. The lung underneath the fourth and fifth ribs was soft and collapsed easily. The new formed osseous tissue over the previous operative area was resected and the bridge of tissue from the first, second, and third vertebrae to the anterior rib ends was separated. An excellent collapse was obtained. Following this stage, there again was a mild wound infection which cleared up after drainage and irrigations.

At present, x-ray (Fig. 4) shows that the cavity previously present in the left upper lobe has been closed by the thoracoplasty and that the oleothorax has maintained a collapse of the right upper lobe. Vital capacity is 1,000 c.c. Patient is slightly dyspneic on exertion but is gradually improving her respiratory function. Sputum has been consistently negative although it totals approximately 2 ounces daily. This is undoubtedly due to associated bronchiectasis. She has gained 15 pounds in weight. She was discharged from the hospital Oct. 12, 1937, for convalescent care at home. In March, 1938, follow-up showed a negative sputum and no x-ray evidence of cavity. General condition was good except for a slight dyspnea on exertion.

SUMMARY

1. The advantages and disadvantages of the use of contralateral oleothorax during the performance of partial thoracoplasty are discussed.

2. Two case histories are presented to illustrate the use of this procedure.

REFERENCES

1. Coryllos, P., and Ornstein, G.: Management of Bilateral Cavernous Pulmonary Tuberculosis, J. THORACIC SURG. 5: 337, 1936.
2. Jessen, Harold: Thoracoplasty in Bilateral Cavernous Tuberculosis, J. THORACIC SURG. 4: 1, 1934.

EXTRAPLEURAL APICOLYSIS

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GLEN GARDNER, N. J.

SINCE the establishment of thoracoplasty as a valuable asset in the treatment of pulmonary tuberculosis, certain types of upper lung cavities have been recognized as notoriously difficult to close. To obviate this difficulty, various supplementary operations have been described and advised and have been proved valuable adjuncts to our armamentarium. With the advent of extrafascial apicolysis as described by Semb,[4] it was felt that, by its employment, patients might possibly be saved one or more operations.

We felt that a collapse which was from above downward as well as lateralward would aid materially in bringing about the closure of cavities that might otherwise remain open. The usual technique of an upper rib thoracoplasty affords a lateral collapse only, as the apical attachments are not released. Therefore the Semb type of operation was undertaken. It was used routinely at first, but later we restricted the procedure to the large apical cavities and to those which we considered might prove difficult of closure under the standard procedure. In so doing we have met a type of complications which was quite unexpected and one which sheds more light upon the indications and contraindications for this technique.

Our limited experience with the Semb technique has left us with the feeling that there are some very definite advantages to be gained in carefully selected cases, namely:

1. Revision and supplementary operations will be less frequently needed.

2. Postoperative improvement following the first stage is more rapid.

3. Supplementary stages may be postponed for a longer period without endangering the ultimate outcome, if the patient's condition does not seem wholly satisfactory after the usual lapse of two to three weeks.

4. Certain upper lung cavities can be more effectively collapsed than previously.

On the other hand, because of at least two possible complications, certain limitations are placed upon the routine use of the Semb type of operation:

1. Possibility of deep wound infection.

2. Possibility of the interruption of the blood supply to the upper lung tissue with subsequent necrosis.

From the New Jersey Sanatorium, Glen Gardner, N. J.
Received for publication, October 22, 1938.

Of the past fifty consecutive thoracoplasty cases in our service, fourteen have been selected for the Semb technique. Of this fourteen, twelve are now free of tubercle bacilli. One is positive because of a contralateral lesion, and one still has occasional positive concentrated specimens. From a surgical standpoint, all cavities in these last two cases are closed, and it is expected that with adequate care, the outcome will be favorable in both instances. In two cases a single stage was sufficient to render the patient free from sputum and tubercle bacilli. Among the remaining cases, there were 27 operations, making a total of 29 or an average of 2.1 per patient.

Complications were distributed as follows: Pott's disease, 1 case, condition arrested at present without operation; scoliosis, 1 case, not serious enough to be deforming; partial bronchial stenosis, 1 case, condition now apparently arrested although the patient does have some "wheezing" of which she complains at times; deep wound infection, 2 cases; necrosis of lung, 1 case, fatal.

We are inclined to feel that the wound infections are peculiar to this type of operative technique. Neither case showed any unusual reaction following the first stage; in fact, their recovery was surprisingly rapid with but a minimal reaction. As the wound was reopened at the second stage, a small amount of straw-colored or brownish fluid was obtained which was not infected. The dissection was carried further as described by Overholt,[2, 3] after partial resection of the fourth, fifth, and sixth ribs and a portion of the remaining stump of the third. The wound was thoroughly irrigated with saline solution and closed in the usual manner without the customary drainage which we routinely employ in the standard procedure. From then the wound healed by first intention, and sutures were removed on the seventh day. The convalescence was surprisingly uneventful even in the face of the intercurrent infection. Both cases showed the usual temperature and pulse rises suggestive of infection, but at no time was the condition of either patient alarming. In one case, the reaction to the infection occurred within the first week; in the second, the pulse and temperature rise was not noted until almost the fourth week. However, the patient had complained of undue soreness in the region of the third rib stump anteriorly during the third week. The wound in each case was aspirated anteriorly and found to contain pus which was positive for staphylococcus on culture. The wounds were then drained and recovery subsequently was uneventful.

There has been one death, that of a patient who had giant upper lobe excavations on the right (Fig. 1). The patient from the start was a poor operative risk. However, the first stage with apicolysis was completed, and recovery was satisfactory. At the second stage the usual quantity of fluid (brownish) was encountered. The fourth, fifth and sixth ribs were resected in part as well as a portion of the remaining stump of the third. The mobilization of the lung was carried out as described by Overholt.[2, 3]

The wound was closed in layers without drainage. The patient's condition was fairly satisfactory after the first five days. Then in about four and one-half days she took a turn for the worse and died fifteen days postoperative. She was given O_2 by nasal tube intermittently throughout the postoperative period. Autopsy was obtained and showed a terminal cardiac dilatation, but especially a gangrene of the entire lung involved in the operative field. This finding was, of course, staggering and led to much speculation and concern. The conclusion arrived at will be discussed later.

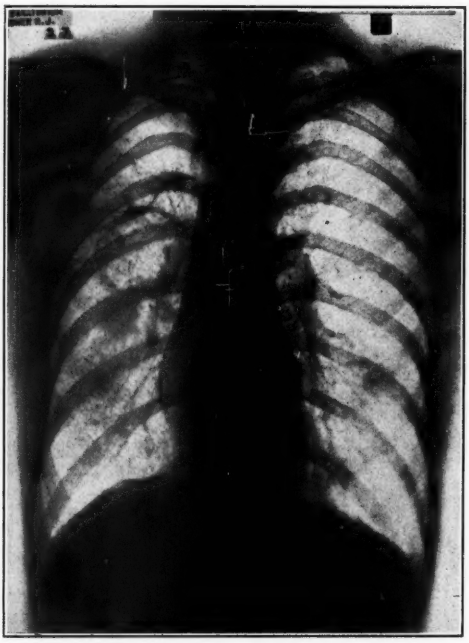

Fig. 1.—Preoperative x-ray of the patient who died. Note the two giant cavities occupying the upper half of the right lung.

The care of these patients preoperatively does not differ from that offered the usual thoracoplasty case. A varied amount of "exercise" is recommended to tone up the cardiovascular system. A thorough study is made of renal and cardiovascular systems, including the usual count determinations, nonprotein nitrogen, sugar, and also vital capacity. Each patient is prepared for transfusion, and the donor is always present whether he be needed or not. Sedation consists of a sedative the evening before, and pantopon gr. ⅓ or morphine gr. ⅙ one-half hour preoperative. Each patient is encouraged to expectorate all sputum possible, using postural drainage the morning of the operation.

Postoperatively all patients are given intravenous 5 per cent glucose 3,000 c.c. and oxygen and carbon dioxide (95 per cent O; 5 per cent CO_2) inhalations. Opiates are given to relieve pain but always with care not to destroy the cough reflex. Should paradoxical motion develop, supports or weights and oxygen are used, depending upon the individual case. As soon as possible each patient is instructed to lie on the operated side with a folded pillow in the armpit. The value of this has been definitely shown in Alexander's clinic as reported by Bisgard.[1] Strict bed rest is maintained as long as possible after all cavities are closed and sputum becomes negative. A period of at least nine months is necessary, and if possible, we feel that a year is more advisable in many cases. Despite considerable opinion to the contrary, it is the author's belief that to vary from this does not give the patient with advanced pulmonary tuberculosis time to heal his lesion adequately, and, as a consequence, the patient's future may be jeopardized very definitely. Furthermore, the operative procedure will be subjected to discredit.

I cannot stress emphatically enough that no surgical procedure is a substitute for bed rest, the foundation upon which all tuberculosis therapy is based. Although a certain few cases seem to be very refractory, we feel that it is essential to strive to obtain a negative sputum, for, otherwise, the patient is certainly a danger to himself as well as to others because he is harboring active pulmonary tuberculosis.

DISCUSSION

Fourteen cases of thoracoplasty with apicolysis, or lung mobilization, are reported. In this group there have occurred two types of complications: wound infection and lung gangrene. Both have occurred after the second stage, and we believe this has something to do with the difficulties encountered.

In the case of wound infections we feel certain that infection was not introduced at the time of operation, although this cannot be conclusively proved in so small a number of cases. However, in retrospect, we are inclined to believe that the rupture of the mediastinal lymphatics during mobilization of lung at the second stage is responsible for the deep wound infection which we encountered. In a group of our cases, not herein reported, a limited extrafascial apicolysis was performed, mobilization being carried out at the first stage only. In none of these cases was such an infection encountered. Because of the limited degree of mobilization, none of the larger mediastinal lymphatics were broken, as the operation was confined to the region of the apex and, therefore, a considerable distance away from the large lymphatics of the hilar region.

Our second complication, gangrene of the lung, presents a far more serious problem, and one which deserves the most careful consideration. As we view the incident, we feel certain that the thin wall of remaining lung and fibrous tissue had been deprived of its usual blood supply be-

cause of the large amount of tuberculous destruction, and that invading blood vessels from the thoracic wall had been maintaining viability. Then, when this shell of tissue was subjected to two stages of mobilization, its only source of blood supply was interrupted and necrosis resulted. Such a possibility never occurred to us preoperatively, but in retrospect, I feel convinced that possibly there would have been no ill result had mobilization been confined solely to the first stage. In the future I feel sure that this occurrence will have a very definite deterring effect upon the performance of a similar extensive apicolysis in cases in which such large excavations exist.

CONCLUSIONS

1. Fourteen cases of extrafascial apicolysis performed during fifty consecutive thoracoplasty cases are reported. A total of twenty-nine operations were performed.

2. Two cases complicated by deep wound infection are reported. It is felt that rupture of the mediastinal lymphatics was the contributing cause.

3. One death resulting from gangrene of the lung was discussed. Interruption of a secondarily established blood supply from the thoracic wall is believed to have been the etiology of this complication.

4. Giant pulmonary excavations are considered as a probable contraindication to lung mobilization.

REFERENCES

1. Bisgard, J. D.: Postural Wedge Compression of Thorax: Aid to Maximal Collapse, Prevention of Scoliosis and Visualization of Possible Residual Cavity After Thoracoplasty, J. THORACIC SURG. **3**: 99, 1933.
2. Overholt, Richard H.: Thoracoplasty With Lung Mobilization, Part 1. The First Stage Operation, Am. Rev. Tuberc. **35**: 411, 1937.
3. Overholt, Richard H.: Thoracoplasty With Lung Mobilization, Part 2. The Second and Subsequent Stage Operations, Am. Rev. Tuberc. **35**: 430, 1937.
4. Semb, C.: Thoracoplasty With Extrafascial Apicolysis, Acta chir. Scandinav. Supp. 37 **76**: 1, 1935.

THORACOPLASTIC COLLAPSE OF ACUTE PROGRESSIVE TUBERCULOSIS

A Report of Five Cases

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Ninette, Man.

THE surgery of pulmonary tuberculosis has made rapid strides forward in the past five to ten years. Its applicability has been widened, largely as a result of changing methods. The mortality and morbidity following operation have been greatly reduced.

Acute progressive pulmonary tuberculosis has been accepted as suitable for collapse by pneumothorax, but not by thoracoplasty. The latter has been considered much too dangerous. I would like to present five cases of pulmonary tuberculosis that were acute and progressive, with a poor, if not hopeless, outlook. Surgery was suggested only as a last resort after pneumothorax had failed and bed rest alone caused no improvement. The patients were fully acquainted with the risk of operation. Each one realized without being told that the future was very dark without aid.

All except one were in their early twenties, and, as it happened, all were women.

The operations were done with fear and trembling of the outcome. Of the five, four are alive and doing well. The fifth, who died, had a very recent acute spread in her contralateral lung just before the operation was begun, and today a patient in similar circumstances would not be considered for operation.

Practically all textbooks and articles on the subject definitely state that thoracoplasty should only be performed on patients with disease of a chronic variety with cavitation, showing evidence of fibrosis, and stationary for some months or longer. For years Dr. Edward Archibald has claimed, "It may be laid down as a safe procedure that the patient who shows no evidence of fibrosis, whose history demonstrates the tendency to activity, and whose lesions are at the moment active, even though the disease be strictly unilateral, should not as a rule be operated upon." As recently as a year ago this question was discussed with Dr. Archibald, and he was still of the same mind but open to persuasion.

The small series that I am presenting fall into the group described by Dr. Archibald as being unfavorable, and unsuited for thoracoplasty. They were all young, and, if the standard contraindications had been adhered to and only the operative results considered, they would not

From the Manitoba Sanatorium, Ninette, Man.
Read (by title) before the Twenty-First Annual Meeting of the American Association for Thoracic Surgery at Atlanta, Ga., April 4, 5, 6, 1938.

have been operated upon, and all, no doubt, would have been left to die. However, considering the individual patients and their youth with the possibility of a long, useful life, it was decided to give them a chance; even if the operative risk were great, the risk of dying seemed greater with conservative treatment. If a pneumothorax could have been instituted in these cases, it would have been carried out, and if a good collapse resulted, the outlook would have been considered much more hopeful. Then why not extend the field of surgery to obtain this collapse in selected acute cases if the surgery is done in easy stages with longer than usual periods between operations? The risk of not operating should be considered as well as the risk of operating. Decision should be based as much, or more, on prognosis as diagnosis.

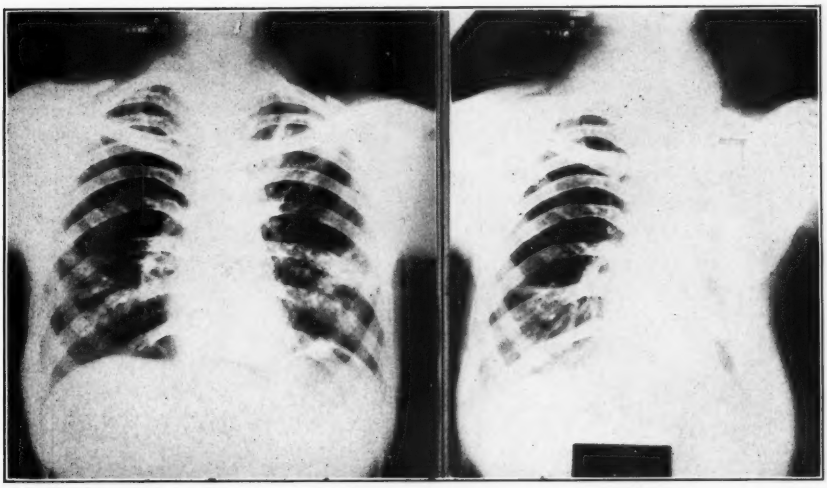
All the operations were performed under local anesthesia in the sanatorium where the patients were closely observed by myself. Operations were thus done at times when conditions appeared most opportune. The greatest deterrent to collapse by thoracoplasty is the thought of a major surgical procedure on an acutely ill patient with progressive disease. Fortunately no untoward incidents occurred during or immediately after the operative collapse in these five cases, the reports of which I will present in detail.

Before proceeding though, I would like to give a general picture of where and under what circumstances this surgery was performed. This work was done at the Manitoba Sanatorium, Ninette, Man., under the direction of the late Dr. D. A. Stewart and Dr. E. L. Ross, the present superintendent. The institution has 285 beds. Since April, 1935, the surgery has been performed in the institution; prior to this, patients had been sent 150 miles to a general hospital. This in itself would practically rule out operation on the type of patient presented in this series. In other words, unless you can operate on the patient right where he is and at the optimum time, results are liable to be discouraging. During the three years since April, 1935, 105 patients have had thoracoplasty completed, with a total of over 300 stages. Of the 105, the early operative mortality is 3 per cent, and the late mortality also 3 per cent. Out of 105, 99 are alive and 75 per cent with no sputum or no tubercle bacilli in it by gastric analysis. Every patient is fully reviewed and discussed at a conference before operation is decided upon. All the operations have been of the newer type with fewer ribs removed at each stage and longer lengths of each rib excised.

CASE REPORTS

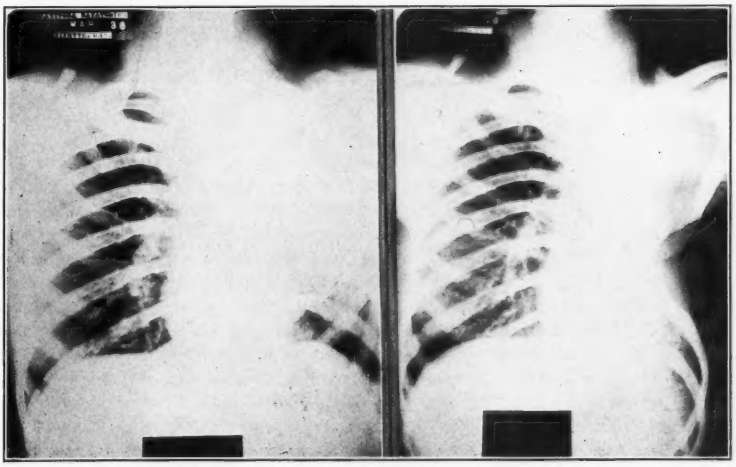
CASE 1.—Mrs. A. A., white, age 21 years, was admitted May, 1934, with a cough, positive sputum, and tuberculous laryngitis. Disease involved the left upper lobe with a 4 cm. cavity. There was also a slight infiltration in the right apex. Left pneumothorax failed. In June, 1934, a left phrenic crush was performed. A postoperative spread developed at the right base. Symptoms did not improve until about four months after the phrenic operation, by which time the left apical cavity had become smaller, but in May, 1935, she developed a severe chest "cold." The

cavity at the left apex enlarged and was accompanied by much coughing and a temperature between 100° and 101°. The left diaphragm was still paralyzed. The course continued to be unfavorable on bed care, and it was decided to proceed with a left thoracoplasty. This was done in three stages, removing eight ribs. She made an uneventful recovery, the last stage being in September, 1935. Symptoms improved and sputum became negative. She was discharged to carry on at home in September, 1936. She is now in good general condition, able to do part of her housework, and a recent chest film and examination were favorable in every respect.



a *b*

Fig. 1.—Case 1, *a*, before operation; *b*, one year after thoracoplasty.



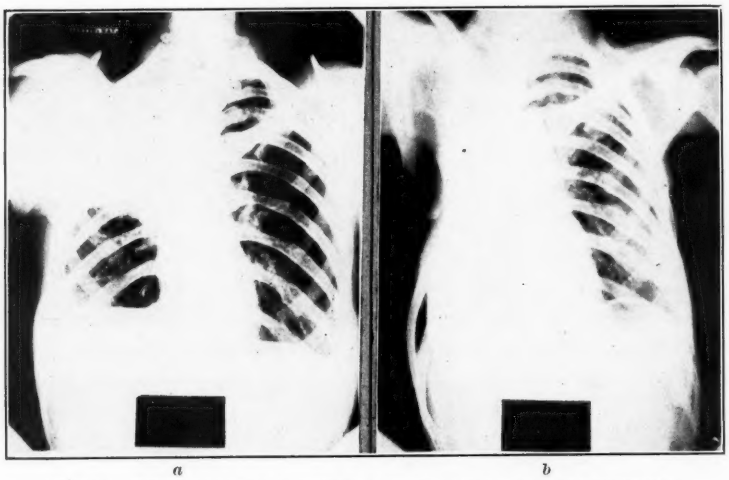
a *b*

Fig. 2.—Case 2, *a*, before operation: *b*, one and one-half years after thoracoplasty.

CASE 2.—Mrs. E. C., white, age 19 years, was admitted in November, 1935. Illness began acutely in June, 1935, with a severe chest "cold." On admission there was a pneumonic process in the left upper lobe with a 5 cm. cavity. Scattered

infiltration was evident in the right lung. Pneumothorax on the left failed. Despite bed care, her condition steadily became worse. She had a troublesome laryngitis and a definite tuberculous enterocolitis. Temperature ranged between 101° and 102°. The cavity in the left apex became much larger and measured 8 cm. In spite of the downward trend, a left thoracoplasty was proceeded with in April, 1936. By three posterior stages eight ribs were removed, and an anterior operation was also performed. Convalescence was stormy after the first and second stages, but after that, recovery was uneventful. Improvement commenced after the collapse was established, and although there was an occasional positive sputum, tubercle bacilli have been absent now for eight months. Both laryngeal and intestinal symptoms have entirely disappeared, and the patient has improved beyond recognition.

CASE 3.—A. G., white female, age 25 years, graduate nurse, was admitted April, 1936, with caseous pneumonic disease in the right upper and middle lobes. There was no single cavity but a great deal of honeycombing. The onset was very acute,

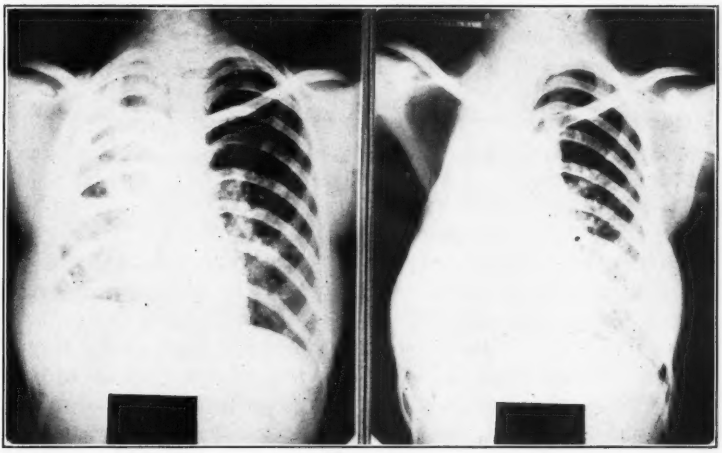


a *b*

Fig. 3.—Case 3, *a*, before operation; *b*, three months after thoracoplasty.

and she had been treated for seven weeks as having an ordinary pneumonia. In spite of bed care she failed to respond; in fact, the course was steadily downwards. Temperature ranged from 101° and 103° and often rose to 104°. Pneumothorax failed. Despite the very acute course, in July, 1936, a right thoracoplasty was decided upon, even in the face of active intestinal lesions and laryngeal involvement. Owing to the intense summer heat, operation was postponed for a month. A new film before operation showed fresh active-looking disease in the contralateral lung which heretofore had been clear. This practically changed our ideas about operation, but at the patient's own insistence we proceeded. A three-stage posterior thoracoplasty was completed, removing seven ribs. Convalescence was stormy following the first operation, but she gradually improved and there was marked improvement following the second operation. Her condition was good until about two weeks after this operation when intestinal symptoms became very troublesome. In order to complete the collapse, a third stage was performed to remove the sixth and seventh ribs. Although cough and sputum were definitely improved, the disease in the contralateral lung steadily progressed, and the intestinal symptoms were very marked. She died three and one-half months after the thoracoplasty was completed.

CASE 4.—V. S., single, white female, student nurse, age 19 years, was admitted in August, 1936, with caseous pneumonic tuberculosis in right upper lobe with a 5 cm. cavity and productive disease in left lower lobe. Right pneumothorax was begun, but, owing to wide apical adhesions which could not be severed by thoracoscope and cautery, we decided to abandon the pneumothorax. An effusion developed which became purulent and was accompanied by moderate fever. The pus was repeatedly aspirated and the lung gradually re-expanded, but, in spite of this, a bronchopleural fistula developed in August, 1937. Following this she became very ill, with temperature of 100° to 103° and a great deal of irritating cough. Disease in the contralateral lung showed a definite increase. Despite the unfavorable course, thoracoplasty was proceeded with on the right side. Seven ribs were removed by three posterior operations and one anterior. Convalescence was uneventful with temperature dropping down below 100°. After the third stage, for about three weeks temperature became elevated again to 100° and 101° F., but it soon subsided and her condition has steadily improved. The disease in the left lung has been stationary, and although there is still an occasional positive sputum, the empyema has entirely cleared and the bronchopleural fistula has completely closed.

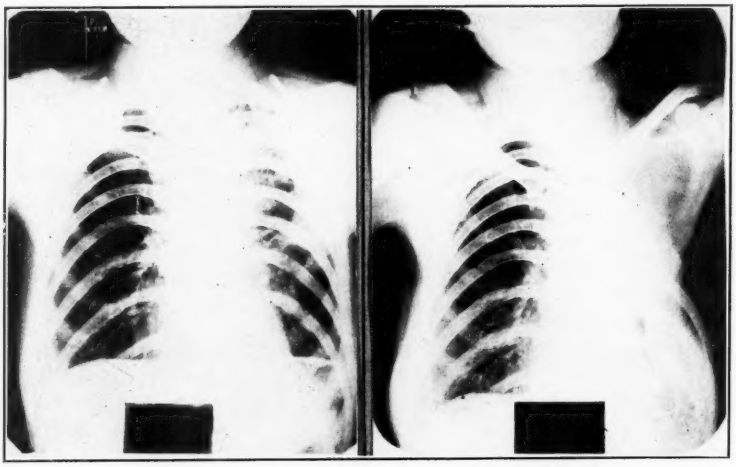


a *b*

Fig. 4.—Case 4, *a*, before operation; *b*, one month after thoracoplasty.

CASE 5.—A. McC., single, white female, graduate nurse, was admitted July, 1937, with moderately advanced disease in the left upper lobe. There was evidence of honeycombing but no distinct cavitation. For several years prior to admission she was examined because of familial contact. A minimal lesion had been present in the left apex for five years. In April, 1937, prior to admission, a film showed slightly more infiltration, and rest was advised but not taken. From April to July, 1937, the increase in disease was rapid. Left pneumothorax was attempted but failed, and she was kept on bed care. In spite of this, she developed a troublesome tracheobronchitis and laryngitis. Her condition steadily became worse and in six weeks new films showed distinctly more disease and more evidence of cavitation. The contralateral lung was still clear. Temperature was gradually rising and was close to 101° every evening. In spite of the progression of disease, a left thoracoplasty was proceeded with and seven ribs were removed. Recovery was excellent, both

cough and sputum entirely disappeared after the last operation, and no positive sputum was recovered since one month after operation. It is only six months since the operations were completed, but in that time she has gained about 20 pounds in weight and has no symptoms whatsoever.



a *b*

Fig. 5.—Case 5, *a*, before operation; *b*, four months after thoracoplasty.

This series of five cases, of course, is much too short to permit any emphatic conclusions to be drawn, but it at least should suggest that our views regarding the indications and contraindications for thoracoplasty may profitably be revised. With four out of five responding favorably, we have 80 per cent good results even in this unfavorable group.

In closing, I would like to propose that our indications for thoracoplasty be made less rigid. This operation might be used for patients who have either acute, subacute or chronic caseous pneumonic tuberculosis and on whom pneumothorax or some other minor operation has failed. Disease should be predominantly unilateral, but, if bilateral, at least the disease in the contralateral lung should be stationary or controlled.

THE IMMEDIATE EFFECT OF SCALENIOTOMY UPON THE SIZE OF APICAL TUBERCULOUS CAVITIES

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KOCHS, Els, and Junkersdorf[1] in 1930, and Gale and Middleton[2] independently in 1931, first reported the effects of scaleniotomy in pulmonary tuberculosis. Since then a number of accounts of the results of this operation have appeared. The largest series, 135 patients, has been reported by Fisher.[3] One hundred and twenty-five of these patients had cavities. Thirty patient were terminal cases on admission. In the remaining ninety-five patients, thirty-four cavities (35.8 per cent) were closed by scaleniotomy with or subsequent to phrenicectomy. The majority of the cavities which were closed had a diameter of from 2 to 4 cm. On the other hand, Brown and Atkinson,[4] reporting their experiences with fifteen patients, conclude that the clinical results do not warrant the performance of the operation. The diversity of these and other reported results emphasizes the difficulty in evaluating the operation of scaleniotomy. This diversity apparently depends upon the extent of the patient's disease and the criteria employed in estimating a favorable result.

Minor collapse measures are not infrequently employed on patients who will ultimately require more extensive surgery but who are judged to be temporarily too ill to withstand a radical operation. Again, they are often employed in patients where the lesion might possibly become healed after the minor procedure but where such a favorable result is unlikely. Phrenicectomy or scaleniotomy performed upon the above two classes of patients may be definitely beneficial, but if the results are estimated in terms of closure of the cavity and the disappearance of tubercle bacilli from the sputum, they will be disappointing. If the minor collapse measure is employed in small cavities where the expectation is that no further surgical intervention will be necessary, and the clinical result is estimated eight months or a year later, then it is difficult to distinguish the exact role played by the surgical procedure. The effect of prolonged rest, unless previously shown to be without effect, might be responsible for a good result. Thus the reported results of phrenicectomy, and more recently of scaleniotomy, upon tuberculous lesions are difficult to evaluate.

In the operative treatment of cavernous lesions of the lung a method is desirable which accurately measures the size of the cavity shortly

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From the "A" Surgical Service of the Pennsylvania Hospital, Philadelphia, Pa.

before and shortly after the surgical procedure. Such a method would permit a more exact evaluation of the operation. The present report deals with thirteen patients with pulmonary tuberculosis, treated at the Pennsylvania Hospital.* In all of these patients, the area of the cavity was measured accurately shortly before and after the performance of scaleniotomy. Anteroposterior x-ray films using the Potter-Bucky diaphragm were made two to sixteen days before operation and five to seventeen days after operation. The distance of the patients from the film was the same with both exposures. The area of the cavities was measured by Douglas' gravimetric method.[5] With a strong light behind the film, a good grade of bond paper was laid on

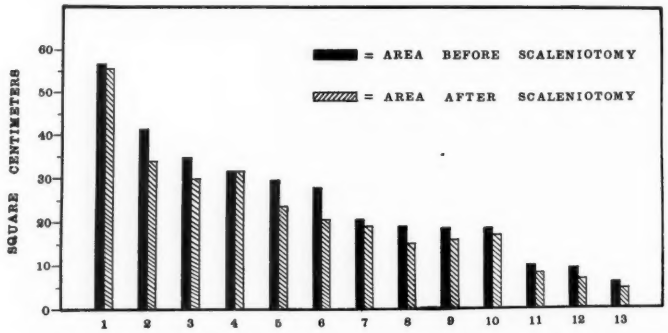

Fig. 1.—Graphic representation of the cross-sectional area of pulmonary cavities immediately before and after scaleniotomy in thirteen patients.

the film and the outline of each cavity traced upon it. Three tracings were made of the same cavity in each film. The paper enclosed by the tracings was then cut out and weighed on a chemical balance. The average of the three weights was used. The weight of one square centimeter of bond paper was determined by averaging the weights of six pieces of paper 10 cm. square and dividing by 100. The areas of the cavities were then computed in square centimeters by dividing the average weight of the paper silhouettes of each cavity by the weight of one square centimeter of paper.

Fig. 1 is a graphic representation of the areas of the cavities before and after scaleniotomy. The patients are arranged in order of the size of the cavity from 1 to 13. In all the patients, except Nos. 1 and 4 in whom there was no appreciable change in the size of the cavity, there was a decrease in the area of the cavity of from 7 to 27 per cent. In patient No. 1 there was a 2.3 per cent decrease, and in patient No. 4 there was an 0.3 per cent increase. In order to be sure that the

*I am indebted to Dr. John B. Flick for permission to include four of his patients in this series.

cavities did not appear smaller because of a decrease in the total shadow of the thorax on the x-ray film, measurements of the transverse diameter of the thorax were made on each film at the level of the ninth thoracic vertebra. The differences in this measurement before and after scaleniotomy were in every instance insignificant. In patients Nos. 3, 4, 6, 7, 10, 11, and 13, the phrenic nerve was interrupted at the same time that the scaleniotomy was performed. As can be seen this interruption of the phrenic nerve in a little more than half of the patients apparently had no consistent bearing on the decrease in size of the cavity.

We do not know of any accurate method of measuring the volume of pulmonary tuberculous cavities. However, most pulmonary cavities tend to conform roughly to the shape of a prolate spheroid, i.e., the figure formed by the rotation of an ellipse about its major axis. The volume of a prolate spheroid can be calculated by the formula $4/3\,\pi\,ab^2$, where a and b are the major and minor semiaxes respectively. The greatest diameter of the cavity was taken to be the major axis. The minor axis is a line bisecting the major axis and perpendicular to it. As all the cavities were irregular in outline this estimation of volume was, of course, only an approximation to the true value.

Fig. 2 is a graphic representation of the volumes of the cavities estimated by this method. The patients were arranged in the same order as in Fig. 1, i.e., in the order of decreasing cross-sectional area of the cavities. As can be seen, the estimated volumes do not fall into quite the same decreasing order. The decrease in volume after scaleniotomy varied from 4 to 56 per cent. The method is not as accurate as the paper-weight method but serves to illustrate the fact that an observed decrease in cross-sectional area usually represents an appreciably greater decrease in volume.*

It is not the purpose of this paper to report the end results of scaleniotomy, but a brief account of the subsequent course of these patients will be given. Most of the patients had the type of disease which required thoracoplasty. In ten patients the diameters of the cavities varied from 5.6 cm. to 11.4 cm. The other three patients had cavities varying from 3.3 to 4.5 cm. Six patients (Nos. 1, 3, 5, 7, 8, and 9) have had thoracoplasties completed or in the process of completion. In one of these six patients (No. 9), there was an interval of four

*It is evident from a consideration of the formulas for the area of an ellipse and the volume of a prolate spheroid that a diminution of the major axis will result in a percentage reduction in area of the ellipse which will be equal to the percentage reduction in the volume of the prolate spheroid; a diminution of the minor axis will result in a percentage reduction in area of the ellipse which will be smaller than the percentage reduction in volume of the prolate spheroid. The relation of the percentage reduction in area (RA) to the percentage reduction in volume (RV) when the decrease occurs in the minor axis can be expressed by the following equation, where x is the ratio of the smaller to the larger minor axis: $\frac{RA}{RV} = \frac{1-x^2}{1-x}$. In these patients, there was, in most instances, some reduction in the minor axis as well as in the major axis of the cavities, since the percentage reduction in volume was usually greater than the percentage reduction in area.

months between the scaleniotomy and the first stage of the thoracoplasty, during which time the cavity, which had shown an immediate decrease in size, increased to more than its original dimensions. In one patient (No. 2), thoracoplasty was advised but was refused. Four patients had extensive bilateral disease and were considered poor risks for thoracoplasty. Scaleniotomy was performed in the hope of improving the conditions of these patients sufficiently to permit the performance of thoracoplasty. In three of these patients (Nos. 4, 6, and 11) the disease has continued to progress bilaterally, and thoracoplasty is thought to be contraindicated. In one patient (No. 10), scaleniotomy has been performed too recently to determine the clinical effects. One patient (No. 13) has shown steady improvement, but the cavity is not completely closed. Finally, in one patient (No. 12), the cavity became closed two months after scaleniotomy.

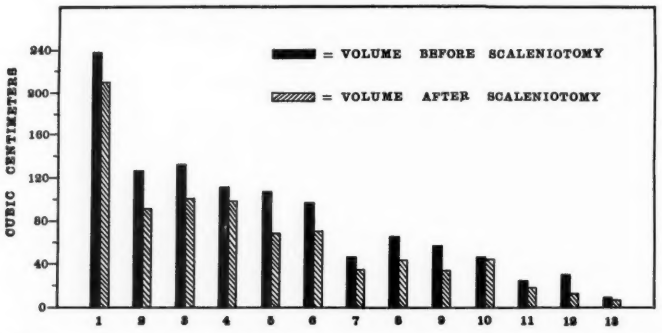

Fig. 2.—Graphic representation of the estimated volumes of pulmonary cavities immediately before and after scaleniotomy in the same patients.

From our experience with these patients we believe that the operation of scaleniotomy may be performed with benefit prior to the first stage of a thoracoplasty. In fact, it might be regarded as the first stage of a very gradual collapse of the lung produced by multiple operations, each one of which produces a progressive diminution in the size of the cavity. Our experience with the smaller type of cavitation in which Fisher obtained his best results has been limited. However, in one case with a cavity 4.5 cm. in diameter, the cavity closed two months after scaleniotomy; another patient with a cavity 3.3 cm. in diameter has shown progressive improvement. Where the operation precedes thoracoplasty we feel that two or three weeks is sufficient interval between the scaleniotomy and the first stage of the thoracoplasty, as the patient may lose ground during a longer interval. Also, in these cases we do not believe that the phrenic nerve should be crushed or cut because of the interference with cough during the subsequent thoracoplasty.

SUMMARY

1. The immediate effect of scaleniotomy upon the size of tuberculous cavities in the upper lobes of the lungs has been studied in thirteen patients.

2. The areas of the cavities have been accurately measured before and after scaleniotomy by weighing paper outlines of the cavities. Two cavities showed no significant change in area after scaleniotomy. The others showed a 7 to 27 per cent decrease in area.

3. A rough estimate of the volume of the cavities immediately before and after scaleniotomy was also made. A decrease in volume of from 4 to 56 per cent was observed.

CONCLUSIONS

Scaleniotomy produces a fairly consistent and immediate decrease in the size of tuberculous cavities in the upper portion of the lung. When the cavities are large, the operation should be followed within a few weeks by thoracoplasty, and, in these patients, the phrenic nerve should not be interrupted. In the smaller cavities where the chances of closure are fairly good, the phrenic nerve should be crushed at the time of the scaleniotomy and an interval of several months allowed to elapse before considering further collapse measures.

REFERENCES

1. Kochs, Els, and Junkersdorf: Tierexperimentelle und klinische Versuche, den therapeutischen Erfolg der Phrenicusexhairese durch Resektion des Scalenusmuskeln zu steigern, Beitr. z. Klin. d. Tuberk. **75**: 772, 1930.
2. Gale, J. W., and Middleton, W. S.: Scaleniotomy in the Surgical Treatment of Pulmonary Tuberculosis, Arch. Surg. **23**: 38, 1931.
3. Fisher, L.: Scaleniotomy With or Subsequent to Phrenicectomy in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. **4**: 41, 1934.
4. Brown, A. L., and Atkinson, K. J.: An Evaluation of Scaleniotomy Accompanying Phrenic Evulsion, Am. Rev. Tubere. **28**: 176, 1933.
5. Douglas, B.: A Gravimetric Method for Determining the Superficial Area of Wounds, Ann. Surg. **73**: 673, 1921.

INTERPOSITION OF COLON FOLLOWING RIGHT PHRENIC NERVE INTERRUPTION

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INTERPOSITION of the colon between the liver and the right hemidiaphragm was first observed roentgenologically by Béclere[1] in 1899 although his ante-mortem diagnosis was a mistaken one of subdiaphragmatic abscess. Chilaiditi,[2] in 1910, was the first to discuss at length the etiologic aspects of this condition, and since then, many cases have been reported either as hepatoptosis or as hepatodiaphragmatic interposition of the colon, a designation introduced by Podkaminsky.[3] Although most authors have observed that, in some of the cases, associated lesions affecting the tone and function of the right diaphragm have been present which might be related etiologically to the interposition, such findings have not been constant, and up to 1929, when Just[4] wrote an exhaustive review of the subject, there had been no cases reported in which interposition had apparently followed operative paralysis of the phrenic nerve. Since then, however, several cases have been reported following this operation for the treatment of pulmonary tuberculosis, the first in 1934 by Roloff,[5] two more by Slavin,[6] and a fourth case by Kommerell.[7] The purpose of the present communication is to report three additional cases of hepatodiaphragmatic interposition of the colon following induced phrenic paralysis.

CASE 1.—W. P., a 45-year-old man, had a right phrenic nerve-crushing operation performed in Loomis Sanatorium in November, 1935, for moderately advanced pulmonary tuberculosis. This resulted in paralyzing and elevating the right diaphragm. Subsequent serial roentgenographs of the chest revealed nothing unusual until August, 1936, when a zone of diminished density appeared between the liver and the right diaphragm (Fig. 1). This persisted in later films and showed some evidence of the presence of intestinal haustrations. A barium enema revealed that the first portion of the transverse colon was situated, in the form of a loop, anterior to and partially above the liver, interposed between the latter and the diaphragm (Figs. 2 and 3). The interposition has persisted since its establishment, having been demonstrated at the patient's last follow-up examination two years and four months after the operation as well as at all intervening examinations. Although the operation was a phrenicophraxis and not an exairesis, regeneration of the nerve has apparently not occurred as the diaphragm is still paralyzed. On physical examination at various times there has been more or less obliteration of the normal area of liver dullness, depending, apparently, on the degree of gaseous distention of the displaced loop of the colon. There have been no serious symptoms associated

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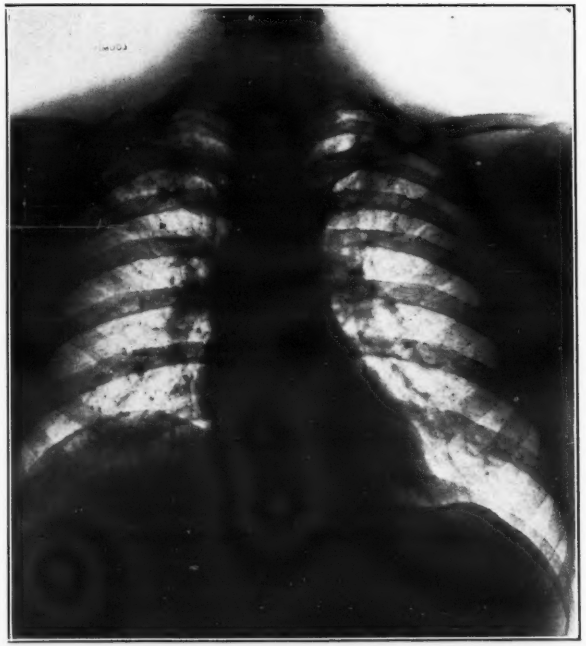

Fig. 1.

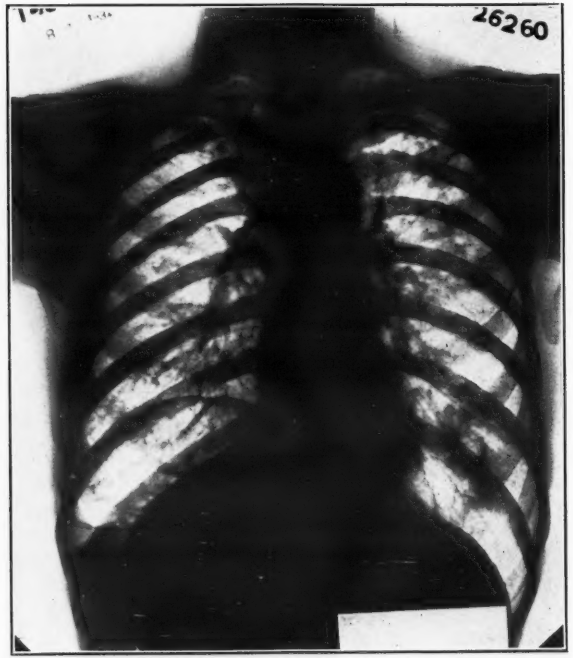

Fig. 2.

Fig. 1.—Case 1. Interposition of colon. The interposed segment of colon appears in the chest film as a zone of diminished density between the diaphragm and the dome of the liver.

Fig. 2.—Case 1. Barium enema.

with the condition, but the patient is frequently conscious of "gas in the chest," accompanied by slight pain, and there has been some increased tendency to constipation.

Fig. 3.—Case 1. Barium enema, lateral view.

CASE 2.—Mrs. A. S., a 50-year-old woman, had had a right phrenicectomy performed in January, 1929, prior to her admission to Loomis Sanatorium. Evidence of interposition in the form of a distinct subdiaphragmatic area of rarefaction with clearly recognizable intestinal haustrations was first noted in the roentgenograph made of the chest during September, 1929. It persisted in subsequent serial roentgenographs up to November, 1932, when the patient left the sanatorium. No barium enema was given in this case so that it was not definitely proved that the interposed viscus was a segment of the colon, but the characteristic appearance of the chest film leaves little doubt that this was another case of hepatodiaphragmatic interposition of some portion of the large bowel. The patient at various times complained of anorexia, occasional vomiting, and alternating constipation and diarrhea, all of which symptoms may have been due to intestinal tuberculosis, which was not ruled out, rather than to the interposition. The patient died two years after leaving the sanatorium of a posthemorrhagic tuberculous bronchopneumonia. An autopsy was not performed.

CASE 3.—W. B., a 43-year-old man, was admitted to Bellevue Hospital in July, 1934, with a history of having been treated for pulmonary tuberculosis since 1928 and of having had a right artificial pneumothorax induced in 1929. This, however,

was abandoned after a month and a half, following which a right phrenicectomy was performed. He had had a recent recurrence of respiratory symptoms with a hemoptysis on the day before admission. There was no history of symptoms referable to the gastrointestinal tract. A roentgenograph of the chest taken three days after admission revealed nothing unusual about the right diaphragm except its high position. A second roentgenograph taken six days later revealed, in addition to the elevation of the right diaphragm, an apparent separation of the latter from the dome of the liver by the interposition of a large gas bubble (Fig. 4). The presence of distinct haustral markings clearly indicates that the gas was contained in a segment of bowel and, together with the absence of gas under the left diaphragm, differentiates the condition roentgenologically from pneumoperitoneum. Roentgenographs taken one month and five and one-half months after the first one failed to reveal the gas bubble. The patient was a drug addict and repeatedly left the hospital against advice before his final visit in June, 1936, when a roentgenograph of the chest again showed the interposition. There is no definite evidence that the interposition was actually, as well as apparently, intermittent in this case because a barium enema was not given, which, as Uspensky[8] has pointed out, is the only way to differentiate the intermittent from the permanent interpositions.

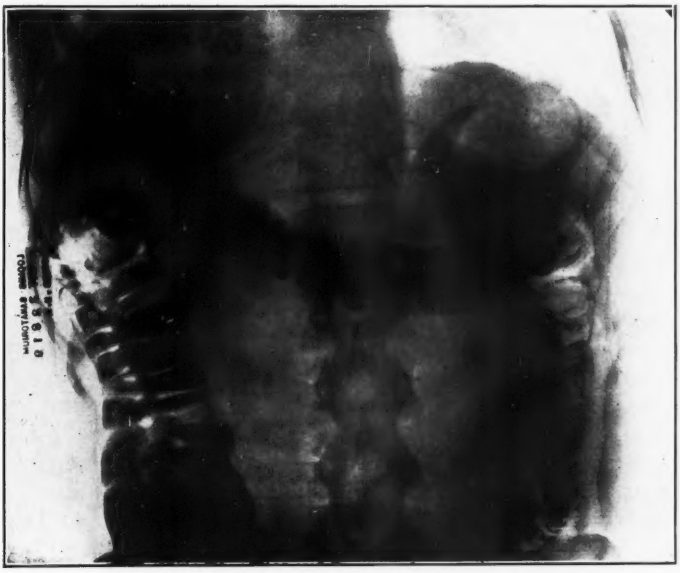

Fig. 4.—Case 3. Interposition of colon. Intestinal haustrations are more clearly defined than in Case 1 (Fig. 1).

DISCUSSION

The possibility of an etiologic relationship between the operative paralysis of the right phrenic nerve and diaphragm and the interposition of the colon in the above cases cannot be disregarded. Although lesions affecting the diaphragm are not essential to permit interposition,

there is considerable evidence that they may, when present, be one of several contributing causes. Slavin's[6] two cases of interposition following induced phrenic paralysis were found among 141 cases in which the right phrenic nerve avulsions were done. This is a considerably higher incidence of interposition than that reported by Uspensky[8] for cases occurring without previous phrenic nerve operations, of which he found 22 cases in a series of 26,000 roentgen examinations of the chest. In the Tuberculosis Service of Bellevue Hospital, where roentgenographs of the chest are taken of virtually all of the three thousand or more patients admitted yearly, we have seen only one case of interposition, over a period of ten years, which was unassociated with paralysis of the diaphragm.

The symptomatology of interposition of the colon seems usually not to be very serious, and it is probably rarely that surgical intervention is necessary. The indications for such intervention and the operative methods employable have been reviewed by Just.[4] When interposition occurs in association with phrenic paralysis it must be remembered that not all of the gastrointestinal symptoms which may be present are necessarily related to the interposition itself because they may be due in part, or even wholly, to the displacements of other abdominal viscera. Lichtenstein[9] has shown that a high transverse position of the stomach is the usual sequel of left phrenic paralysis and its associated elevation of the diaphragm. Although he states that symptoms are rarely associated with such displacements of the stomach, others, notably Ballon,[10] Wilson, Singer and Graham, Hecht,[11] Maendl and Schwarzmann,[12] Welles,[13] and Harper,[14] have observed them more frequently. When present they consist most commonly of anorexia, nausea and vomiting, rarely giving rise to pain. In interposition the symptoms are more likely to be pain, frequently located in the chest, and constipation or even recurrent obstipation as reported by Kemmerell.[7] Complete intestinal obstruction resulting from the visceral displacements appears to be rarely encountered whether the displacement is of the stomach or of the colon. Stanbury[15] has reported several cases of gastroduodenal obstruction following induced phrenic paralysis which terminated fatally, but whether this was related to the mechanical or to other factors seems uncertain. The cases of volvulus of the stomach, one of them fatal, reported by Bonafé and Poulain,[16] would seem to be more clearly related to the preceding phrenicectomies. Whether or not phrenic nerve operations may rarely lead to such fatal sequelae, experience demonstrates that, occasionally, they are followed by gastrointestinal disturbances of sufficient severity to merit consideration among the possible ill effects against which the possible benefits of this type of therapy must be balanced when it is contemplated for any particular case.

SUMMARY

Three cases of hepatodiaphragmatic interposition of the colon following induced phrenic paralysis are reported.

The possible etiologic relationship between the operation and the subsequent development of interposition is discussed.

The symptomatology and significance of "postphrenic" interposition of the colon are discussed.

REFERENCES

1. Béclere, A.: Abces sous-phrénique en communication avec les bronches, révelé par l'examination radioscopiques trois ans aprés le début de la maladie, Bull. et mém. Soc. méd. d. Hôp. de Paris **16**: 485, 1899; Rectification d'une erreur de diagnostic: Ectopie du colon transverse, ibid. **16**: 506, 1899.
2. Chilaiditi, D.: Zur Frage der Hepatoptose und Ptose im Allgemeinem, Fortschr. a. d. Geb. d. Röntgenstrahlen **16**: 173, 1910-1911.
3. Podkaminsky, N. A.: Zur Frage nach den Ursachen der Interposition von Organen zwischen Diaphragma und Leber, Fortschr. a. d. Geb. d. Röntgenstrahlen **36**: 327, 1927.
4. Just, E.: Zur Frage der Interpositio Colonis, Deutsche Ztschr. f. Chir. **220**: 334, 1929.
5. Roloff, W.: Dauerfolge der Lungenkollapsbehandlung, Ergeb. d. ges. Tuberk.-Forsch. **6**: 285, 1934.
6. Slavin, P.: Interposition of Colon Following Induced Phrenic Paralysis, Am. J. Roentgenol. **33**: 481, 1935.
7. Kommerell, B.: Dystopie des Kolons nach Phrenicusexairese, Röntgenpraxis **8**: 102, 1936.
8. Uspensky, A.: Die pathogenetische Bedeutung des Symptomenkomplexes der "Interpositio Colonis," Fortschr. a. d. Geb. d. Röntgenstrahlen **37**: 540, 1928.
9. Lichtenstein, H.: Form- und Lageveränderungen des Magens nach Phrenicusexairese, Beitr. z. Klin. d. Tuberk. **80**: 509, 1932.
10. Ballon, H. C., Wilson, H. M., Singer, J. J., and Graham, E. A.: Esophagus, Stomach and Heart Following Unilateral Phrenicectomy, Arch. Surg. **21**: 1291, 1930.
11. Hecht, P.: Phrenicusexairese und Gastrokardialer Symptomenkomplex, Beitr. z. Klin. d. Tuberk. **70**: 336, 1928.
12. Maendl, H., and Schwarzmann, E.: Unsere Erfahrungen bei 100 Phrenicoexairesen, Beitr. z. Klin. d. Tuberk. **71**: 80, 1929.
13. Welles, E. S.: Phrenicectomy in Three Hundred Cases of Pulmonary Tuberculosis, Arch. Surg. **19**: 1169, 1929.
14. Harper, F. R.: Effect of Phrenic Nerve Interruption on the Gastrointestinal Tract, J. Thoracic Surg. **7**: 398, 1938.
15. Stanbury, W. S.: Anatomical Changes in the Diaphragm Following Phrenicectomy, Am. Rev. Tuberc. **29**: 528, 1934.
16. Bonafé and Poulain: Contribution à l'étude des troubles gastriques consécutifs à la phrénicectomie: Volvulus de l'estomac, Presse méd. **40**: (part 2) 1104, 1932.

A NEW TECHNIQUE FOR PHRENIC CRUSH

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OPERATION upon the phrenic nerve for treatment of lower lobe tuberculosis was first advocated by Steurtz in 1911. Goetze, a pioneer in this field, did an exceedingly radical operation which consisted not only in the resection of the phrenic and accessory phrenic nerves but also the division of the cervical sympathetic fibers that enter the main phrenic nerve. Goetze's operation fell into disfavor, and for it was substituted avulsion or exeresis of the phrenic nerve as suggested by Thiersch and first performed by Willie Felix. Before a meeting of the American Association for Thoracic Surgeons in 1932, Barnwell suggested the possibility of the harmful influence of permanent phrenic paralysis. Goetze, Kroh, Bakes, and Fisher occasionally performed temporary paralysis of the phrenic nerve as early as 1920.

The results obtained in our first 100 cases of phrenic avulsion were presented before the Southern Surgical Association in 1929. The fact was appreciated that other methods of treatment of the disease in the lung might become necessary, especially where there was bilateral involvement. It was also realized that permanent paralysis of the hemidiaphragm was undesirable, and, therefore, in 1932 we ceased doing the avulsion operation and substituted the crushing operation. The operation which we performed consisted in crushing the main phrenic nerve for one centimeter, the resection of large segments of any accessory nerves, and the division of the nerve to the subclavius muscle. Only 50 per cent of the cases were successful as evidenced by a total paralysis of the diaphragm. Of the 50 per cent which were unsatisfactory, one-half showed only partial paralysis of the diaphragm; in the other half of these cases where an apparent paralysis was first produced, diaphragmatic movement became re-established in an average time of three months. As all of the operations had been most carefully done, it became evident to us that other connections entering the phrenic nerve below the clavicle must exist. We therefore developed the following technique:

The usual transverse incision for exposure of the phrenic nerve is employed. The accessory phrenic nerves are divided. The nerve to the subclavius muscle is resectioned as before. The phrenic nerve is then crushed for approximately one centimeter and drawn upward into the neck for three and one-half or four centimeters. We thought that, by so drawing the nerve upward, any filaments entering the phrenic

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nerve below the clavicle might be torn and hence the resulting paralysis of the diaphragm would last a much longer time. The incision is closed with subcuticular suture of fine silk with a split shot on each end of it.

That our deductions were well founded is proved by the following series of cases. Since January, 1935, the operation as above described has been routinely employed. We have operated upon 246 patients and in every one complete paralysis of the diaphragm ensued. Following this type of operation the diaphragm remains paralyzed on an average of from ten to twelve months. Diaphragmatic movement then begins, although that structure itself remains elevated. The amount of diaphragmatic excursion increases, and within two to three months, the diaphragm has returned to its normal position and normal respiratory movement.

SUMMARY

A new method of phrenic crush is presented. By the employment of this technique the diaphragm remains paralyzed from ten to twelve months. An additional two to three months are required following the re-establishment of diaphragmatic motion before that structure returns to its normal position and full respiratory excursion.

REFERENCES

1. Goetze: Quoted by Davis: Brit. M. J., February, 1926.
2. Thiersch: Quoted by Davis: Brit. M. J., February, 1926.
3. Kroh: John Alexander, Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C. Thomas, p. 146.
4. Bakes: John Alexander, Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C. Thomas, p. 146.
5. Fisher: John Alexander, Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C. Thomas, p. 146.
6. Goetze: John Alexander, Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C. Thomas, p. 146.

TECHNIQUE OF EXTRAPLEURAL PNEUMOTHORAX*

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THROUGH the entire history of artificial pneumothorax for pulmonary tuberculosis, some method has been eagerly sought that would effectually supplant this procedure when pleural symphysis has precluded the utilization of this intrapleural space.

In 1891, Tuffier[1] excised the lung apex and attempted unsuccessfully to maintain the space created by the frequent introduction of nitrogen. Baer,[2] in 1913, introduced paraffin. While in certain cases this is of value, it has proved efficient in but a very limited number of cases. Toy balloons have been inserted,[3] as well as elastic materials, gauze, muscle flaps, and other endogenous and exogenous substances. Only in isolated cases have the results been satisfactory.[4]

After Tuffier's early series the first definite reports on the separation of the lung between the parietal pleura and the endothoracic fascia were made by Mayer[5] and Schottmuller.[6] In subsequent years a number of workers have attempted this operation: Ulrici,[7] Eden,[8] Ranzi,[9] Riviere and Romanis,[10] Sebestyen,[11] and Joannides and Shapiro.[12]

Despite many attempts through the years by a number of men, this procedure attracted little enthusiasm. Cases not favorable for collapse by pneumothorax were selected; the correct extrapleural layer for separation was not followed; the extrapleural space was early lost, or air-refills were too infrequently given. Certainly extrapleural pneumothorax as a method of treatment of pulmonary tuberculosis did not attract serious attention until recently. Graf,[13] in 1934, developed a technique that, with certain important modifications by Schmidt and his group,[14] seems to have at last established a method for maintaining selective collapse in pulmonary tuberculosis when attempts at establishing an intrapleural pneumothorax have been unsuccessful. In our series, now totaling more than eighty cases as of July 1, 1938, we are following closely, except for minor variations, the technique so admirably worked out by Graf and Schmidt.

OPERATIVE TECHNIQUE

As a rule, if well borne by the patient, local anesthesia is to be preferred to general. The danger of explosion in using the cautery or high frequency current for the control of bleeding vessels and in keeping the illuminated retractor constantly within the thorax is thus eliminated. The immediate postoperative reaction is considerably lessened. At Olive View Sanatorium we use a

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barbiturate the night before operation but none the morning of surgery if we are using avertin. In addition to nembutal grains 3 (0.2 gm.) two hours before surgery, and pantopon grain ⅙ (0.02 gm.) with scopolamine 1/200 (0.0003 gm.) a half hour before operation, we occasionally administer by rectum 2 c.c. of avertin twenty minutes before the patient leaves his room for surgery. The patient is thus rendered sufficiently drowsy so that, with adequate infiltration and gentleness of technique, 1 per cent novocain as the local anesthetic sufficiently controls the pain. We do not hesitate, however, if during the stripping of the parietal pleura from the chest wall the patient becomes restless, to put him under cyclopropane general anesthesia, or if the patient is apprehensive or prefers, we administer cyclopropane general anesthesia before surgery commences.

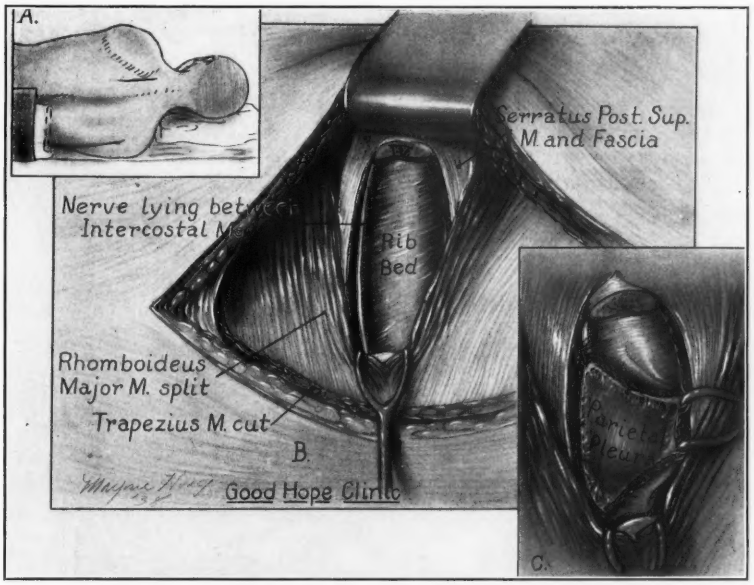

Fig. 1.—*A*, Insert shows position of patient; *B*, approach through muscles to rib bed; *C*, incision below rib bed through endothoracic fascia to parietal pleura.

An incision 12 to 16 cm. long is made parallel to and along the lateral border of the erector spinae muscle, begun approximately 4 cm. below the trapezial ridge and carried directly downward or with a slight obliquity outward. The trapezius muscle is divided. Often adequate exposure is obtained by separating the fibers of the rhomboideus major over the rib of which a portion is to be excised. There is considerably less postoperative discomfort if this muscle is left intact, although, if exposure is not satisfactory, we do not hesitate to cut the rhomboid throughout the length of the wound. While a section of the third rib is often the site when the pulmonary involvement does not extend below the fifth rib, it is usually somewhat more advantageous to resect a piece of the fourth rib, since if the lung needs to be stripped to the seventh rib, it cannot be easily accomplished at a point higher than this. The fifth rib has in some cases been resected to allow very extensive extrapleural dissection.

The belly of the serratus posticus superior is easily recognized over the third rib, whereas over the fourth it is thinned out to little more than fascia. A

curvilinear incision may be made through this, somewhat above or below the portion of rib to be removed in order to form a flap whose suture line at closure is not directly superimposed over the divided intercostal muscles. A direct and careful division of the muscle directly over the rib, however, has not proved to interfere with eventual airtight approximation of the muscle edges. It seems, therefore, largely a matter of the operator's choice.

The periosteum overlying the rib is cleanly divided with care not to injure either this or the intercostal muscles, since their integrity is necessary for a satisfactory closure. Approximately 8 cm. of the fourth or third rib is then removed, beginning somewhat distal to the corresponding transverse process. It is of advantage then to identify in its bed between the internal and external intercostal muscles the intercostal nerve which is removed throughout the extent of the wound. This not only lessens postoperative pain in this region but makes the introduction of air and subsequent refills much more free of discomfort should this site be chosen for the introduction of air. Immediately below the periosteum which represents the bed of the section of rib removed, the fibers of the internal intercostal can be distinctly seen. These fibers are easily elevated and divided in a straight line along the course of the rib resection.

Fig. 2.—Finger separating chest wall from parietal pleura rather than parietal pleura from chest wall.

Immediately beneath this lies the very tenuous endothoracic fascia which in this location, owing to its thinness, often cannot be surely identified. When recognition is possible, however, fibers can be seen running, in general, parallel to each other with tiny vessels lying superficially. External to this endothoracic fascia, adherence is quite firm both to the internal intercostal muscle and the rib periosteum. While separation in this space is possible yet it is often difficult and is uniformly attended with considerable hemorrhage. In the subfascial plane, however, that is, between the endothoracic fascia and the parietal pleura, if no inflammatory reaction has

thickened them, the attachment is exceedingly thin. Surprisingly fragile and delicate, rather widely separated fibrous processes unite these two structures so that with little pressure the parietal pleura is easily separated from the overlying endothoracic fascia. This is the so-called "optimum plane" or the "richtige schicht" described by Schmidt.

With the subfascial plane identified, the forefinger, with the palmar surface outward, is introduced in this stratum, and the parietal pleura with the lung beneath is gently stripped from the chest wall using pressure not against the parietal pleura but against the chest wall itself at the subfascial junction of these two structures. Often it is found that either above or below, mesially or laterally, the parietal pleura is firmly adherent to the overlying fascia. It is then necessary to abandon temporarily the stripping in this region, and having found a spot where the parietal pleura can be more easily freed, to follow this and in the end approach the adherent area from within outward or above downward, as the case may be. It is not unusual even then to find that though the pressure exerted by finger or instrument be considerable, the parietal pleura cannot with safety be separated from the overlying structure. In that event, over that particular locality it becomes necessary to establish an extrafascial line of separation and, when this particular area has been freed, to connect the two by sharp dissection, returning to the optimum plane beneath the endothoracic fascia.

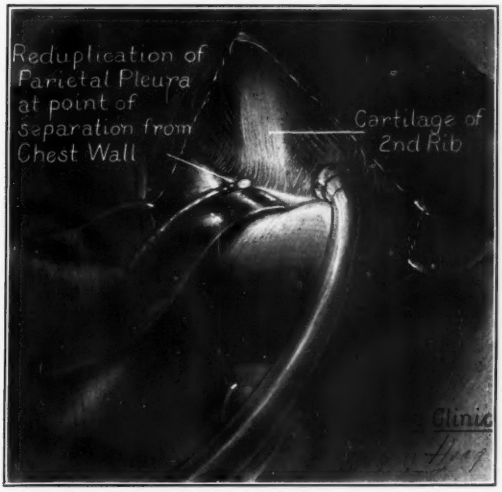

Fig. 3.—Surgical view showing reduplication of parietal pleura. Suction tip used for pleural stripping. Illuminated retractor in place.

After the lung is freed immediately about the chest wall opening, an illuminated brain retractor or a Cameron light incorporated into a retractor is introduced into the opening in order that from then on enlargement of the extrapleural space may be done under direct vision. With this light adequately illuminating the space, stripping is continued either by using the distal end of a blunt suction tube or a small sponge on a sponge forceps. It is preferable to use the latter instrument possessing a moderate curve in order that its presence may not interfere with the view within this intrathoracic space.

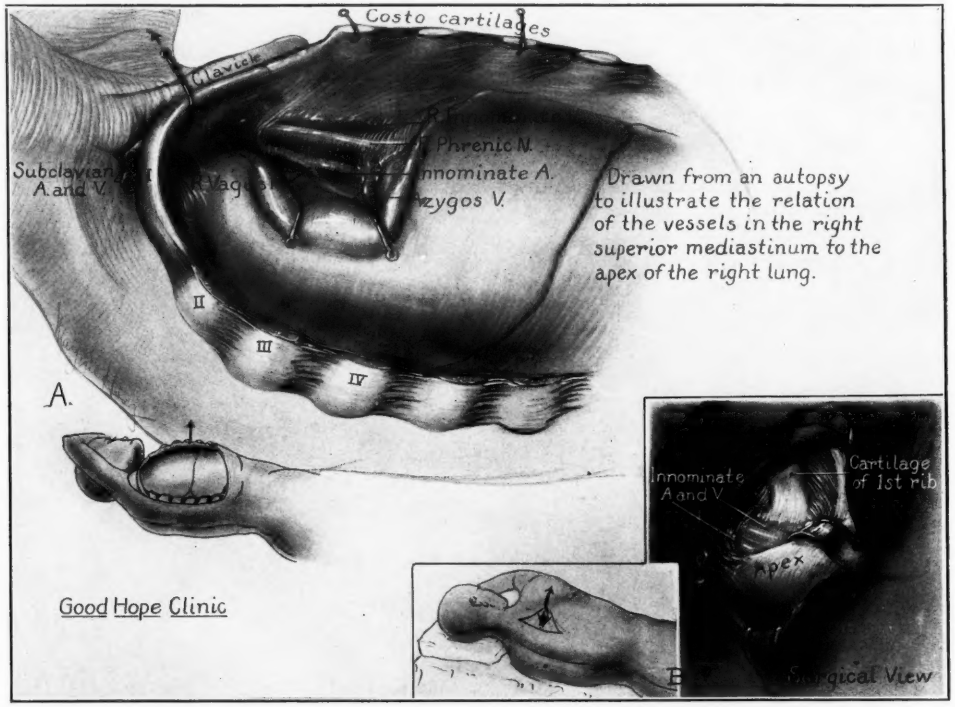

Fig. 4.—*A*, Looking into right superior mediastinum with lung slightly retracted; *B*, surgical view of same structures as seen in *A*.

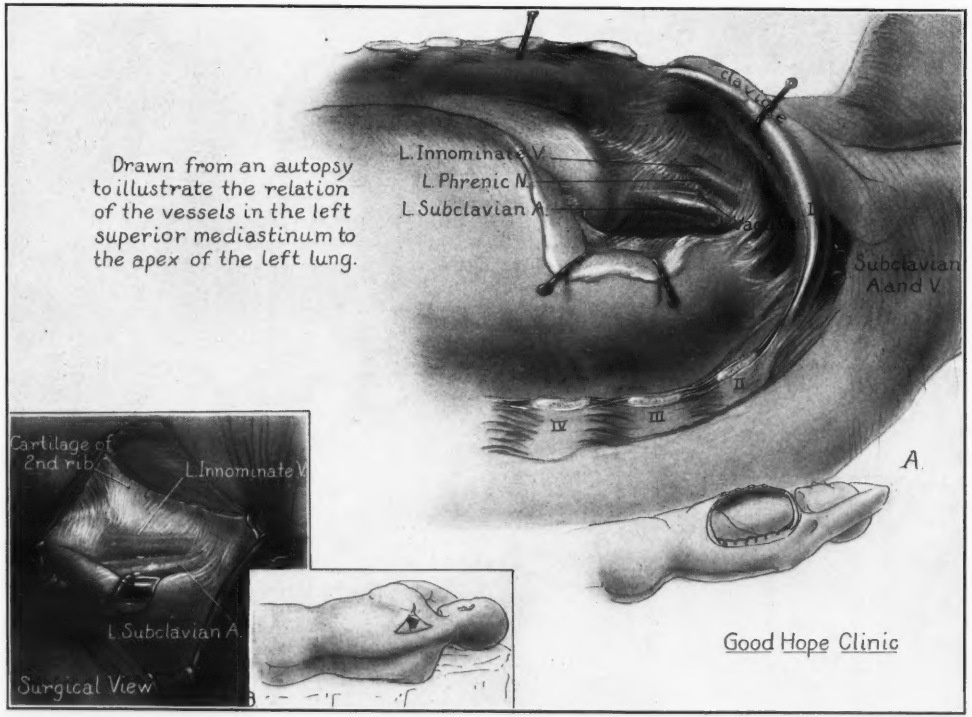

Fig. 5.—*A*, Looking into left superior mediastinum with lung slightly retracted; *B*, surgical view of same structures as seen in *A*.

It is of great advantage to strip the lung free into the gutter early since it is by this procedure that a maximum space for the continuation of the stripping under direct vision may be obtained. Gradually the lung is freed from behind forward until the cartilage of the second rib is easily discernible. Stripping is continued from below upward to the apex. At this stage the endothoracic fascia can be more clearly identified at the apex of the lung where it is greatly strengthened by the fascia described by Sibson, Sebileau[15] and Truffert.[16]

Sebileau (1892) classifies these fascial extensions schematically as so-called ligaments over the apex substantially as follows:

1. A transversopleural ligament from the transverse process of the seventh, and sometimes sixth, cervical vertebra to the pleural dome and at once to the first rib behind the anterior scalenus muscle, containing occasionally a few muscle fibers whose presence furnishes the excuse of identifying it as the scalenus minimus muscle.

2. A costopleural ligament from the collum of the first rib to the pleural dome.

3. A vertebropleural ligament from the anterior side of the lower cervical vertebrae to the medial part of the pleural dome.

Truffert's subsequent investigations (1931), however, make it seem somewhat doubtful whether these structures are actually isolated preformed bands. It is his opinion that they form a continuous fibrous structure by which the pleural dome is suspended and from which fibers extend fanlike to embrace the large vessels of the superior mediastinum upward through the thoracic aperture. The point of surgical importance of this fibrous dome suspending the apex is that it is often necessary under direct vision to divide these fascial attachments which can be plainly seen at the apex of the lung somewhat posterior to the great vessels. If there has been considerable inflammatory reaction at the apex, they become firm solid structures that must be divided by scissors in order that the apex may be freed. When these fibrous bands are divided it is seldom difficult with sponge or the blunt nose of the suction tube to free the lung from above downward to the hilum. Usually the vessels lying immediately beneath are plainly visible. On the right the innominate vein lies well anterior to the innominate artery, and as the hilum is approached the bulging azygos vein is easily visible lying transversely across the mediastinum. On the left, due to the fact that the subclavian artery comes directly from the arch of the aorta, the former structure is much more prominent. The innominate vein is not often seen since it lies anterior and somewhat deep to the artery. The arch, however, quickly appears as the lung is stripped downward from the mediastinum. It is seldom that marked adherence exists over these vessels, and with the moderate pressure required to free the parietal pleura from the mediastinum, there is little danger of injuring them.

It is important that the floor of this extrapleural space be made as flat as possible and that the lung be freed approximately 4 cm. below the level of tuberculous involvement. Indeed, in those cases where the extrapleural space has been lost due to lung re-expansion followed by adherence to the chest wall, we have felt that faulty development of the extrapleural floor plus one or more of the following were contributing factors:

1. The lung which becomes the floor of this extrapleural space was not at right angles with the chest wall. The closer the two surfaces approximate each other, the greater the danger of their becoming adherent.

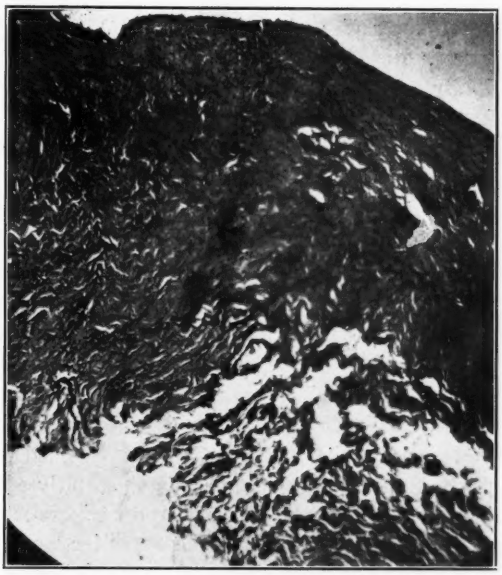

Fig. 6.—Reduplicated endothoracic fascia excised during second stage of a two-stage establishment of extrapleural space for pneumothorax, showing promptness in development of mesothelial layer following lung separation in this plane. (×120)

2. The lung was not freed well below the area involved. Adherence still remained firm between the parietal pleura and endothoracic fascia and not only resulted in incomplete collapse of the tuberculous tissue, but by its presence, there persisted a strong tendency for the lung to return to the chest wall by gradually increasing circumferential adhesions.

3. If the separation was made extrafascially rather than along the optimum subfascial plane, these raw surfaces were very difficult to keep apart, whereas the mesial surface of the endothoracic fascia soon would

develop a mesothelial covering that would become almost as smooth as the parietal pleura itself and show little tendency to adhere to the lung deep to it.

If it is necessary to free the lung to the seventh rib posteriorly, it should be separated anteriorly to the third interchondral space in order that the floor may be approximately flat. In order to prevent drying of the extrapleural surface, it is often advantageous to cover the lung with a warm moist sponge as stripping is being carried on at a more distant point.

After the extrapleural space is satisfactorily established, it is washed out thoroughly with warm saline solution. If bleeding points persist, electric coagulation will control them. At the time of closure all the saline solution may be aspirated or the space left filled with it. Theoretically the presence of the fluid in the extrapleural space should lessen the possibility of lung re-expansion before the subsequent introduction of air. Actually, however, the presence of the air alone has generally proved sufficient to maintain this space temporarily. Since at the first postoperative introduction of air the fluid should be aspirated anyway, it may be satisfactory to close the wound with the extrapleural space dry rather than to leave fluid within it.

The wound is closed without drainage with continuous chromic catgut No. 1 or silk if it is preferred. Great care should be exercised to approximate the intercostal muscles and serratus posticus superior as snugly as possible although it is seldom that the escape of air after the first forty-eight hours seriously interferes with the maintenance of the extrapleural space. It is not uncommon twenty-four hours following operation, however, particularly if a patient has coughed considerably, to find that the lung under the fluoroscope is apparently completely re-expanded. A prompt introduction of air uniformly re-establishes the space without appreciable loss through the operative wound. Leakage is seldom troublesome after the primary needle introduction of air. The trapezius and rhomboideus major are closed with continuous chromic catgut No. 1. Continuous silk is used for the skin.

It is our custom in immediate postoperative care to have the patient turned frequently from side to side, to induce deep inspirations by carbon dioxide every three hours, and to control carefully the sedatives in order that the danger of atelectasis may be minimized.

The procedures followed to maintain this extrapleural space by the introduction of air differ little, except for a few important particulars, from those required for intrapleural pneumothorax. Provided fluoroscopic examination twenty-four hours after operation shows the space to be still evident, the introduction of air is first accomplished on the first or second postoperative day depending on roentgenologic or

fluoroscopic findings. It may be introduced either through the first or second interspace, usually somewhat lateral to the midclavicular line, or posteriorly just mesial to the upper half of the operative wound in the neighborhood of the rib resection. The anterior approach is usually more convenient. A longer needle than for intrapleural pneumothorax is necessary since the distance into the space here is greater. The initial refill may vary from 50 to 200 c.c. A manometer graduated to sixty or more centimeters of water must be employed since the positive pressure often runs from plus 30 to 50. As a rule, by the end of three weeks the patient is on a weekly schedule although the instillation of air may have to be repeated every day or two in the beginning. In the first few refills, until the space has been well-established, it is better to keep the positive pressure in the neighborhood of plus 30 provided this is sufficient to hold the space originally established. A convenient method is to have the needle attached both to the water manometer and to a 100 c.c. syringe, utilizing a three-way connecting valve. The original pressure is recorded; then under syringe pressure a known amount of air is injected, the pressure being frequently checked by turning the stop valve. The portable pneumothorax machine to which one has become accustomed can be used, although, of course, to obtain these higher pressures the levels separating the two bottles must be considerably farther apart.

The patient is liable to exactly the same complications that are possible during the course of intrapleural pneumothorax although the danger of spontaneous lung rupture is much less since the parietal pleura present over the lung is an added protection against tear. When infection develops, whether tuberculous, pyogenic, or mixed, toxicity may be less marked than when such a complication develops between the pleural leaves. Following Schmidt's recommendation, the infected fluid is aspirated, the space is thoroughly rinsed out with saline solution, and approximately 10 c.c. of 2.5 per cent gomenol in oil is introduced. At weekly intervals this procedure is repeated, using larger volumes of gomenol in oil. Unless absolutely necessary, it is inadvisable to drain the space externally.

Should a perforation into a tuberculous cavity occur, it should be closed tightly at once, if possible, in order that the establishment of a bronchopleural fistula may be prevented.

Where no complications occur the emphysema in the region of the wound disappears within three or four days. There is usually a moderate febrile reaction up to 101° F. during the first four days, following which the temperature usually returns to normal.

It is essential that the cases for extrapleural pneumothorax be carefully selected. The indications may be conveniently divided into

absolute and relative. The absolute indication for extrapleural pneumothorax exists when, were the pleural leaves not adherent, intrapleural pneumothorax could be confidently expected to effect an arrest of a given tuberculous process. This includes cases in which the involvement is comparatively recent, the cavity or cavities are still soft-walled with no great retraction of the lobe involved nor displacement of the mediastinal structures, there is no marked contralateral involvement, and the patient is in good general condition. In this type of case the results have been uniformly favorable. The sputum promptly becomes negative; the cough disappears; the disease to all intents and purposes is apparently arrested.

The so-called relative indications confront us, on the other hand, when the tuberculous process is of long standing and the cavity walls are thick and firm. Extrapleural pneumothorax has not proved as dramatically beneficial in this group. While a large percentage of these patients are improved, yet complete cavity obliteration often does not occur. Tubercle bacilli still may be found in the sputum. It is questionable when the enthusiasm now felt for this procedure subsides whether a partial thoracoplasty combined with apicolysis may not often be the procedure of choice. When there is marked retraction of the lung with fibrosis and large thick-walled cavities, it is the opinion of the writers that, while a temporarily pleasing extrapleural space may be established, a limited thoracoplasty with apical stripping according to the method of Semb[17] would be generally the procedure of choice. Extrapleural pneumothorax in such situations we hold to be contraindicated unless the initial improvement following it may render a particular patient a better risk for subsequent thoracoplasty.

Graf's published series of more than one hundred cases and Schmidt's of three hundred, representing a series developed over a period of approximately three years, still leave us uncertain as to the ultimate fate of the lung and the extrapleural space. Where the original indications were absolute, it seems probable that when eventually lung re-expansion seems desirable, it can be expected with considerable confidence to take place, although this has by no means yet been proved. We do know, however, that a certain percentage will lose their space through lung re-expansion, that some will have to have the pneumothorax indefinitely continued, that in others oleothorax will be established, and that unquestionably in many a local thoracoplasty may be required to obliterate the space. With all these possibilities in mind, it certainly behooves us to select the cases very carefully for this procedure, and he who most rigidly adheres to the absolute indications before consenting to establish this extrapleural

space will, in the end, be most likely to have the highest percentage of patients who will have no regret for the years that they were required to continue their extrapleural pneumothorax treatment.

REFERENCES

1. Tuffier, Th.: Semaine méd. **11**: 202, 1891; ibid. **12**: 257, 1892; Bull. et mém. Soc. d. chirurgiens de Paris, 1895.
2. Baer, G.: München. med. Wchnschr. **60**: 1587, 1913.
3. Monod, R.: Mém. Acad. de chir. **63**: 836, 1937.
4. Alexander, J.: The Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C. Thomas.
5. Mayer, A.: Deutsche med. Wchnschr. **39**: 2347, 1913.
6. Schottmuller: Zentralbl. f. d. ges. Tuberk.-Forsch. **11**: 327, 1917; Deutsche med. Wchnschr. **40**: 619, 1918.
7. Ulrici, H.: Deutsche med. Wchnschr. **40**: 1221, 1918; Tubercle **3**: 162, 1922.
8. Eden, R.: Deutsche med. Wchnschr. **40**: 798, 1918.
9. Ranzi, E.: Wien. med. Wchnschr., 1968, 1922.
10. Riviere, C., and Romanis, W. H. C.: Lancet **1**: 531, 1923.
11. Sebestyen, J.: Zentralbl. f. d. ges. Tuberk.-Forsch. **65**: 220, 1932.
12. Joannides, M., and Shapiro, P.: J. THORACIC SURG. **3**: 315, 1934.
13. Graf, W.: Deutsche med. Wchnschr. **62**: 632 and 671, 1936; **63**: 4, 1937.
14. Schmidt, W.: Beitr. z. Klin. d. Tuberk. **88**: 689, 1936; ibid. **91**: 121, 1938; Rev. de la tubere. **3**: 112, 1937.
15. Sebileau, P.: Bull. Soc. anat. de Par. **66**: 410, 1891.
16. Truffert, P.: Arch. med.-chir. de l'app. respir. **6**: 199, 1931.
17. Semb, C.: Acta chir. Scandinav. **76**: 6, 1935.

PENETRATING GUNSHOT AND STAB WOUNDS OF THE THORAX

Report of Eighty-Seven Cases

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IN CIVIL practice, the treatment of wounds inflicted by acts of violence is not a problem of major importance, so far as incidence is concerned, but the emergency may, at some time, have to be met by the surgeon in almost any community. Those of us who practice in industrial centers, where there is a large negro or foreign population, have the greatest opportunity to gain experience in the treatment of thoracic injuries. The present study is based on a series of 171 gunshot and stab wounds of the chest, of which eighty-seven were penetrating wounds, observed in the last ten years, from 1927 to 1937, at the Akron City Hospital.

In the last five years, only four studies based on large series of cases of chest wounds have been reported in the American literature. The greatest series have been reported from the Emory University Division of the Grady Hospital in Atlanta, by Elkin[1] and by Boland.[2] The report of the former was based on a series of 533 patients seen in the period between 1931 and 1935. Boland's report concerned 1,009 patients with penetrating wounds of the chest, studied at that institution during a fourteen-year period, 1922 to 1935. Bigger[3] has reported a series of forty-nine cases, observed at the Medical College of Virginia Hospitals, in two years; and Connors and Stenbuck[4] published a detailed study on sixty-eight cases. Thorough discussions of the subject of chest injuries have also been presented by Bohrer[5] and Hedblom.[6]

CLASSIFICATION

Wounds of the chest are generally classified as penetrating or nonpenetrating, with mention of the type of injury, that is, gunshot or stab wound. Bohrer divides thoracic injuries into three classifications: (1) those involving the structures external to the thoracic cage; (2) those involving the superficial parts as well as the deeper structures; and (3) those involving injuries to the thoracic cage. In his first classification, the only injuries of importance are lesions of the upper anterior chest which involve the brachial plexus or the subclavian vein or artery, and infected stab wounds of the costal cartilage. Most of the thoracic in-

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juries of surgical interest fall into his second classification, that is, penetrating injuries. Injuries to the thoracic cage include fractures of the ribs or sternum.

When the cases of penetrating wounds were classified as to the type of injury, fifty, or 57 per cent, were gunshot wounds and thirty-seven, or 43 per cent, were stab wounds. In Boland's series, 79 per cent were stab wounds, and 21 per cent, gunshot wounds. This probably can be accounted for by the fact that the patients were negroes, who seem to prefer the knife as a weapon.

SYMPTOMS

The most common symptom observed in this series of cases was dyspnea, which was present in approximately 60 per cent of all cases of penetrating wounds. Chest râles were present in 51 per cent, and coughing, in 48 per cent. Hemoptysis was also a prominent symptom and was present in 43 per cent of the cases. Other symptoms which were observed less frequently in this series include cyanosis, emphysema, hiccough, and painful respiration. In four cases in this series, there were no chest symptoms. Evidence of severe shock was present in 50 per cent.

CHEST COMPLICATIONS

The chest complications observed following gunshot and stab wounds of the chest result usually from hemorrhage, infection, or pressure, either from air or bleeding. Hemothorax, pneumothorax, and pneumohemothorax are the most common sequelae. In this series, hemothorax was the most frequent complication. It was present in 34 per cent of the gunshot wounds, and 40.5 per cent of the stab wounds, an average of 36.7 per cent for the entire series. Pneumothorax was observed in six cases, and pneumohemothorax in ten cases. These figures are somewhat at variance with those reported by other authors.

Other complications in this series due to hemorrhage included four cases of hemopericardium, two of mediastinal hemorrhage, and one of pyohemopneumothorax. Of the infectious complications, empyema developed in three cases, infection of the wound in five cases, pleuritis in twelve cases, pericarditis in three, and pneumonia in ten instances. In addition, there was the case of infected pneumohemothorax, just mentioned. Partial collapse of the lung occurred in ten cases, or 11.5 per cent of the series. In two fatal instances, the lung was sutured. Edema of the lung was recorded in one case. Emphysema was present in twenty-one cases, or 25 per cent.

WOUNDS OF THE HEART AND LARGE VESSELS

In this series, there were four cases in which the wound penetrated the heart, two hearts being sutured, and all four resulted fatally. Two

of them were bullet wounds, and two were stab wounds. In another instance, in which the patient died from gunshot wounds, there were lacerations of the large vessels, probably jugular or subclavian. In a case of stab wound in which the subclavian artery was ligated, the patient survived.

EXTRATHORACIC LESIONS OF THE TRUNK

The diaphragm was penetrated in ten cases of gunshot wounds, and in two of stab wounds in this series. In addition, lesions outside the chest complicated thirty-six cases of gunshot wounds, and two of stab wounds. Intra-abdominal hemorrhage occurred in eight cases with two recoveries. The stomach was perforated in five cases, and the intestines in two, all dying. Other fatal lesions recorded were: perforation of the abdominal aorta, one case; perforation of the common duct, one case; perforation of the esophagus, one case; infarct of the kidney, one case; perforation of the pancreas, one case; severed spinal cord, one case; perforation of the spleen, four cases, with one recovery after splenectomy. In addition there were three cases of perforated liver with one recovery, one case of ruptured kidney that was repaired and from which the patient recovered, and two spinal vertebra injuries with one recovery.

In two cases of stab wounds, there was puncture of the diaphragm with herniation of the omentum into the chest, with one recovery. There were two cases of peritonitis, and one of subhepatic abscess, each resulting fatally. One patient had acute dilatation of the stomach found at autopsy.

DIAGNOSIS OF CHEST INJURIES

The major problem in the diagnosis of chest injuries is to determine whether the wound is penetrating or nonpenetrating. This is not always a simple matter. Some of the so-called cardinal signs of penetration may be found in nonpenetrating wounds, and some penetrating wounds give no signs that the injury extends beyond the chest wall. Stab wounds may give no signs of the direction of laceration of the chest wall. When wounds are sucking or emit foamy blood, it is justifiable to assume that penetration has occurred. As Connors and Stenbuck[4] have pointed out, a sucking wound may occur without penetration, when forced respirations cause air beneath the large muscles of the chest wall to pass back and forth through a superficial wound.

The most important signs and symptoms of penetrating wounds are collapse of the lung, hemothorax or pneumohemothorax, emphysema, expectoration of blood, and pleuritis. The last may occur, however, in nonpenetrating wounds. The roentgenographic examination of patients with chest injuries is a valuable aid in making the diagnosis, although it is not always positive in its findings.

In this series, roentgenograms or fluoroscopic examinations were made in twenty-six cases of stab wounds, and in forty of the cases of gunshot wounds. In the latter type, in addition to disclosing chest lesions, the examinations are useful in localizing the bullet or shot. In nine of the cases of stab wounds and in four of bullet wounds in this series, the radiologic findings either did not confirm, or were somewhat at variance with, the clinical findings. In two instances, the first roentgenologic examinations were reported as showing no abnormality, but later roentgenograms disclosed chest lesions. In one case, the x-ray report suggested air in the soft tissue above the clavicle, but did not disclose any fracture. Operation on this patient showed penetration into the pleural cavity with an abscess of the lung, and a fracture of the first rib. In still another case, the x-ray findings were indefinite, but the clinical findings were positive for penetration of the heart, which was proved by necropsy. In one case of bullet wound, the roentgenograms were negative, and operation showed that the bullet had entered the chest. In another of this type, autopsy showed the bullet in the heart, with perforation of the diaphragm, yet the roengenologist reported that the chest showed no abnormality and that he thought the bullet was in the upper left abdomen. In the other cases in which a diagnosis of penetration was made, in spite of negative roentgenographic reports, the clinical symptoms, such as hemoptysis, dyspnea, or cyanosis were sufficient to make the diagnosis.

The diagnosis in chest wounds is the most important factor in treatment, because each case must be regarded as an individual problem, and the recognition of the original condition, as well as the complications that follow, determines the treatment.

TREATMENT

I have followed a conservative attitude in the treatment of all chest injuries. It is impossible to formulate a rigid set of criteria for surgical intervention, because each case has to be dealt with as indicated by the general condition of the patient and the local conditions in the chest.

Shock.—Shock has to be combated in a large proportion of patients with thoracic injuries. Relief of extensive hemorrhage, if present, and supportive measures first have to be administered. Transfusions are administered promptly if loss of blood has been profound and in this series, transfusions were given in twelve cases. In three instances, autogenous transfusions were administered after citration of blood removed from the pleural or abdominal cavity. The largest number of transfusions given in any one case was three.

Surgical Treatment.—The surgical treatment, both early and late, depends on the nature of the wound and the complications present in the individual case.

The wound is thoroughly disinfected as early as possible, and if necessary, the opening in the chest wall is closed. This is demanded in sucking wounds. In case of bullet wounds, the bullet is removed, if this is easily possible. Ligation of superficial vessels is done, and in some instances, it is necessary to open the thorax in order to control severe hemorrhage from internal bleeding points.

Other procedures that were carried out on the chest include removal of a bullet in sixteen cases and of an ice pick in one; exploration of the supraclavicular fossa, one case; operative repair of chest wounds, eight cases; rib resection, six cases; ligation of the subclavian artery, one case; and thoracotomy, four cases.

The late surgical treatment is directed toward the control of complications.

Hemothorax.—In my opinion, it is best to pursue a conservative attitude toward evacuation of hemothorax. By waiting, one gives the lung a chance to heal before opening the chest and precludes the introduction of infection. As Boland[2] has already pointed out, another reason for leaving hemothorax alone is that the formation of the clot may serve to stop the bleeding. In the forty-nine cases of this series in which hemothorax, pneumohemothorax, or pneumothorax was present, thoracentesis was carried out in only fifteen instances. The largest number of aspirations in any one patient was six. The quantities of fluid removed varied from a few drops to 500 c.c. This experience is similar to that of Bigger[3] who reported that aspirations were necessary in only ten cases of the thirty-seven with these complications. Air may have to be removed from the pleural cavity.

Emphysema.—Emphysema is a common complication in chest wounds, and is treated usually by repair of the laceration through which the air is being introduced, if this can be located and the emphysema is marked.

Infection.—Infections within the chest occurred in only four cases in this series. This number includes three cases of empyema and one of pyohemothorax. Infection of the wound occurred in five instances. In addition, there were ten patients diagnosed as pneumonia cases and twelve with pleuritis. When serious infectious complications ensue following a chest wound, drainage of the purulent area is necessary. In two cases in this series, one of stab wound and one of gunshot wound, operations were performed for the drainage of an infected sinus in the chest wall.

The low incidence of infection in the wounds and of empyema in this series confirms the statements that have been made by several authors lately that these are comparatively rare complications of chest wounds.

Extrathoracic Injuries.—When the condition of patients with chest wounds is complicated by lacerations in other parts of the trunk, the treatment must be directed toward the particular injuries present. If there is penetration through the diaphragm, this should be repaired, after reducing any herniation. In this series, the diaphragm was sutured in five cases with three fatalities. In these five, some other procedure, such as suture of the stomach or liver or exploratory laparotomy, was carried out at the same time. Exploratory laparotomy was performed in two additional cases, in which no abnormalities were found in the abdomen. In another case a ruptured intestine was sutured, and in one an exploratory laminectomy was made which disclosed that the spinal cord was severed at the level of the twelfth dorsal vertebra.

LATE RESULTS

In none of the recent articles on wounds of the chest has there been any report on the results of follow-up study. The type of patients presents a real difficulty in making such a study possible. Those who get shot and stabbed belong, for the most part, to a roving, irresponsible group of the populace and are extremely hard to trace. For these reasons it is impossible to make any definite statements regarding the effect of these injuries on late morbidity or length of life.

MORTALITY

In the series of cases studied, death occurred in seven of the thirty-seven patients with penetrating stab wounds of the chest and in eighteen of the fifty with gunshot wounds. In the former group, three had injuries aside from those of the chest, and two others were suffering from profound shock, on admission. Thirteen of the eighteen patients who died from gunshot wounds had injuries, in some instances multiple injuries, outside the chest. The others all had severe shock. If the fatal cases with injuries aside from the chest are excluded, eight deaths occurred as the result of thoracic injuries alone. This gives a mortality rate of 11.6 per cent for the 69 cases. If the cases with other injuries are included, the mortality rate is 28.7 per cent for the 87 cases.

Of the three patients with stab wounds, one died of hemothorax and shock two days after admission. The second patient had multiple stab wounds which caused severe hemorrhage, and hemothorax, and at the time of death, eleven days after admission, an infection in the chest wall. The third patient was suffering from severe shock on admission as the result of a severed brachial artery. Autopsy, five days later, showed edema and congestion of the lungs with beginning pneumonia, acute fibrinopurulent pleurisy, and partial collapse of the lung.

Of the patients with gunshot wounds, two died from severe shock and pneumonia, four days and seven days after admission. Another died of hemothorax on the second day. The other two were moribund on admission and lived one hour and four hours, respectively. The latter of these had lacerations of the jugular and subclavian vessels, with profuse hemorrhage into the pleural cavity and mediastinum.

Of the patients with gunshot wounds who had extrathoracic lesions, only four survived. One of these had a rupture of the kidney, with intra-abdominal hemorrhage; one had perforation of the liver and intra-abdominal hemorrhage; the third suffered some damage to the second lumbar vertebra; and the fourth had an injury to the spleen which required splenectomy. Three patients with penetration of the diaphragm lived, and seven died.

Of the stab wound cases there were 35 males and 2 females, ages ranging from 21 to 53 years, average 34.8 years.

Of the gunshot cases there were 39 males and 11 females, ages ranging from 2 to 46 years, average 28.2 years.

SUMMARY

A series of 171 cases of gunshot and stab wounds of the chest observed during the last ten years at the Akron City Hospital has been analyzed, with special reference to the penetrating wounds, which numbered eighty-seven. Fifty of these were due to gunshot wounds, and thirty-seven to stab wounds.

The most prominent symptoms observed in this group were dyspnea, cough, hemoptysis, chest râles, emphysema, painful respiration, cyanosis, and hiccough.

The chest complications included hemothorax, pneumohemothorax, and pneumothorax, and also empyema, hemopericardium, infection of the chest wall, partial collapse of the lung, pneumonia, mediastinal hemorrhage, and pleuritis.

There were four cases of penetration of the heart, and two of the large blood vessels of the chest. The diaphragm was penetrated in twelve instances.

Thirty-eight extrathoracic lesions of the trunk were observed. These included perforation of the stomach, the intestines, the esophagus, the liver, the spleen, the common duct, the pancreas and the kidney, and several injuries to the spine and nerves. Peritonitis, subhepatic abscess, and dilatation of the stomach were other complications.

The major problem in diagnosis of chest injuries is to determine whether or not penetration has occurred and then to ascertain the nature and extent of the intrathoracic and extrathoracic injuries.

Treatment depends on the nature of the wound and its complications and is largely expectant or conservative. Some injuries present urgent emergencies which demand immediate operative treatment, while others, after careful study, require operation for the control of complications.

The mortality rate in the total series was 28.7 per cent for 87 cases. If the cases in which there were extrathoracic injuries are excluded from this list, the mortality rate in chest injuries alone was 11.6 per cent for 69 cases.

REFERENCES

1. Elkin, D. C.: Wounds of the Thoracic Viscera, J. A. M. A. **107**: 181, 1936.
2. Boland, F. K.: Chest Wounds in Military and Civil Practice, Mil. Surgeon **81**: 175, 1937.
3. Bigger, I. A.: Penetrating Wounds of the Thorax, Virginia M. Monthly **59**: 705, 1938.
4. Connors, J. F., and Stenbuck, J. B.: Penetrating Stab Wounds and Bullet Wounds of the Chest; Study of 68 Cases Operated Upon Between June 1, 1931, and April 30, 1932, With Description of New Operative Procedure of Extra Pleurization and Exteriorization of Pulmonary Laceration, Ann. Surg. **97**: 528, 1933.
5. Bohrer, J. V.: Thoracic Injuries, New York State J. Med. **35**: 749, 1935.
6. Hedblom, C. A.: Thoracic Injuries, Surg., Gynec. & Obst. **58**: 503, 1934.

GUNSHOT WOUND OF CHEST OF PATIENT WITH ARTIFICIAL PNEUMOTHORAX

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THIS case report is presented because of its unique features. In a review of the literature, I have been unable to find reported an instance in which a bullet traversed a pleural cavity in which the lung had been previously collapsed by artificial pneumothorax therapy.

CASE REPORT

Patient, R. L., aged 23 years, male, white, was admitted to the Vanderbilt University Hospital Oct. 25, 1937, complaining of a gunshot wound of the left chest.

He had been a patient in this hospital two years before this, with the history of a recent contact with pulmonary tuberculosis, and malaise, weakness, loss in weight, cough with expectoration and several hemoptyses, fever and night sweats of one month's duration. There were physical and x-ray signs of unilateral pulmonary tuberculosis involving the left apex, without cavitation. The sputum was positive for acid-fast bacilli. Therapeutic pneumothorax on the left was instituted and maintained thereafter by Dr. Clarence Thomas, with excellent collapse of the lung. Following this, he became symptom-free and was working in a filling station up until the time of readmission. The last refill was seventeen days before readmission.

About forty-five minutes before readmission, he was accidentally shot in the left chest with a .32 caliber pistol at a range of five feet. The bullet pierced his clothing before entering the chest. Following the injury, he had some mild left chest pain, but no dyspnea, cough, sputum, or hemoptysis. The wound of entrance bled only slightly. He walked to meet an ambulance to be brought to the hospital.

On examination, his temperature was 98.6°, pulse 80, respiration 28, blood pressure 150/100. The patient was well nourished and well developed and was in no distress. No dyspnea or cyanosis was present. The heart was displaced moderately to the right. The thorax showed slight flattening with no expansion on the left. Over the left fourth rib anteriorly just lateral to the midclavicular line, there was a sharply circumscribed bullet wound of entrance about six millimeters in diameter, with moderate surrounding tenderness, swelling, and subcutaneous emphysema. The wound did not suck with respirations. There was no wound of exit. In the left chest posteriorly in the region of the eleventh rib just lateral to the spine, there was a bullet palpable immediately beneath the skin, with slight surrounding tenderness, swelling, and subcutaneous emphysema. The path of the bullet indicated that it would have struck the heart had the latter not been displaced moderately to the right. The left chest was hyperresonant throughout; tactile and vocal fremitus diminished; the breath sounds were barely audible. There were no signs of fluid. No râles were present. The right chest was clear. There was no evidence of injury to the heart, abdomen, spine, or spinal cord.

White blood count was 11,450. The only sputum was mucoid in character; no acid-fast bacilli were found on two examinations. Other laboratory studies were normal. An x-ray film of the chest on admission showed a large pneumothorax on the left with almost complete collapse of the lung; a very small amount of fluid at the left base (which had been present before receipt of the wound); an incomplete fracture of the left fourth rib in the anterior axillary line; a fracture of the neck of the eleventh rib; a large foreign body, presumably a lead bullet, lying just

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below the left eleventh costovertebral articulation; the heart displaced moderately to the right (Fig. 1).

Soon after admission, the bullet was removed under local anesthesia. This wound and that of entrance subsequently healed without infection. He was given 1,500 units of tetanus antitoxin. There was no other treatment except symptomatic.

While in the hospital, he had mild left chest pains for the first three days. Otherwise he was entirely asymptomatic. His temperature rose to 100.4° on the second day; the following day and thereafter it remained normal. There was no change in the physical signs in the chest. Thoracentesis was not done. His recovery was uneventful. On the sixth day after admission, he was discharged. Fluoroscopic examination of the chest on discharge revealed the same findings as on admission, except for the absence of the foreign body.

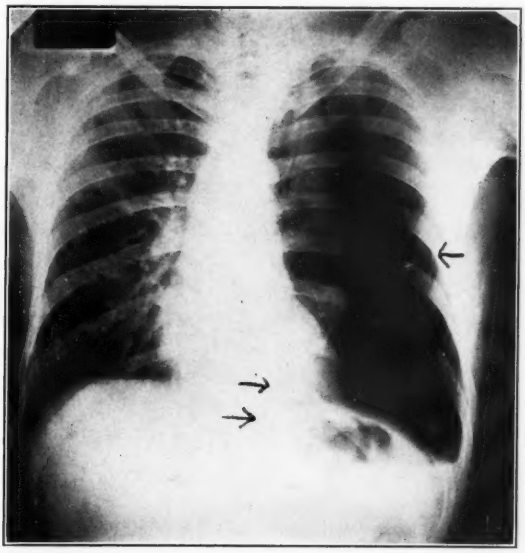

Fig. 1.—X-ray of chest on admission, showing a large pneumothorax with almost complete collapse of the lung, and a very small amount of fluid at the base, on the left; a fracture of the left fourth rib in the anterior axillary line, and of the eleventh rib at the neck; a large foreign body below the left eleventh costovertebral articulation; and the heart displaced moderately to the right.

He returned for observation several times following discharge from the hospital and was last seen twenty-six days after the injury. On Nov. 7, 1937, he received a refill on the left, 100 c.c. of air being introduced. On each occasion he was entirely asymptomatic, the physical signs in the chest remained unchanged, as did the fluoroscopic findings. He had gained in weight and strength and said he felt perfectly well.

COMMENT

In the literature there are recorded numerous cases of wounds of the chest followed by pneumothorax, hemothorax, empyema, and other complications. This case is of interest in that a pneumothorax with complete collapse of the lung already existed prior to the receipt of the wound. The bullet traversed only the chest wall and the pneumothorax cavity, there being no significant injuries other than the rib fractures. Recovery was rapid and uneventful.

EXPERIMENTAL LOBECTOMY USING BRONCHIAL PLUGS

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THE failures in lobectomies are most commonly ascribed to (1) bronchial fistula and (2) hemorrhage.

Infection usually follows bronchial fistulas, and hemorrhage, though it may be primary, not infrequently follows infection. Bronchial fistula, therefore, is the most important complication. The authors feel that the factors producing this complication are:

1. Lateral tension of the bronchial rings,
2. Pressure by the ligature,
3. Intrabronchial-intrathoracic pressure differences.

One or all of the above-mentioned factors tend to cause decubitus perforation of the bronchi at the site of the ligature. In order to overcome some of these mechanical obstacles, it was thought that a method of plugging the bronchus would be advantageous because it would obviate the lateral tension of the bronchial rings as well as the greater part of the pressure of the obliterating ligature.

Numerous types of plugs were experimented with—wax, composite, paraffin, etc.—with varying results. Finally a silver plug was adopted because silver causes little tissue reaction, it is bacteriostatic, and because it could be removed easily.

METHOD

The silver plug consisted of a hollow cylinder open at one end, with a transverse rod at the open end to facilitate removal and a circumventing groove near the closed end to prevent the ligature from slipping (Fig. 1).

Under nembutal anesthesia and positive pressure artificial respiration, an incision was made in the lateral aspect of the right chest of a dog parallel to the ribs. The latter was separated by rib retractors. The lobe to be removed was delivered through the incision and the hilus wiped gently to remove lung tissue. A braided black silk ligature on a straight intestinal needle was sutured (double) about the proximal portion of the hilus so that as much of the serosal tissue as possible remained outside the silk ligature. A longitudinal slit, distal to the tie, was made in the bronchus and a suitable sized plug inserted, open end proximally, until the groove lay at the site of the ligature. After tying, the efficacy of the closure was tested with water for air leakage. The lung was cut away leaving only a small portion of the bronchus distal to the plug. The walls of the bronchus at the cut end were then loosely sewed together, burying the plug. Two lobes were removed in every case in this series. Airtight closure of the chest was made without inflating the lung.

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Following the operation care was taken that the dog was still deeply narcotized; if not, morphine was injected. This step is important because failure occurred when this procedure was not followed. The dogs showed no ill effects following the operation, and after one month the plugs were removed bronchoscopically (by Dr. Holinger).

RESULTS

Following the above method, eight dogs were operated upon, and seven operations were successful without complications or mortality.* Many failures occurred before this method was fully perfected, and they will be discussed later in this paper.

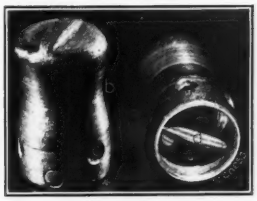

Fig. 1.—Silver plug: *a*, ridge for grasping forceps; *b*, groove for ligature; *c*, holes for drainage; *d*, transverse rod to facilitate movement of plug. (×2.)

The plugs were removed with relative ease where the bronchi were of medium or large size. Small bronchial plugs (4 to 5 mm.) were difficult to remove because they were not visible, and a few of the dogs still retain them with apparently no ill effect. During the time of bronchoscopy, if the silk was freed easily, it was removed; otherwise it was not molested. Bronchoscopically, there was only a slight erythematous reaction about the plugs. Granulation tissue was uniformly absent.

The stump intrathoracically after one month was smooth, grayish-white, and glistening. Occasionally there were adhesions between the stump and a remaining lobe, but this was not constant. Roentgenologic examination after one month showed a moderate shifting of the hilus to the right (side of lobectomy). No evidence of fluid was noted. The intrathoracic pressure on the side of operation, tested in three dogs, showed a return to the normal pressure of about 90 mm. of water (inspiratory) on the first postoperative day. One case examined after three weeks showed a similar pressure.

DISCUSSION

The Lateral Tension of the Bronchial Rings.—When the bronchi are tied separately, or the stump is tied en masse, or the bronchus inverted and edges approximated, there is created a certain amount of lateral tension by the compressed bronchial rings which may eventually cause a decubitus perforation at the site of the ligature. This is especially

*The eighth dog developed distemper, infected his wound, and died on the thirteenth postoperative day with an empyema of the right chest cavity. The plugs were in place, and there were no decubitus perforations about the ligatures.

true immediately distal to the tie where a certain amount of necrosis takes place. In the first two instances, i.e., with bronchi tied separately, or stump tied en masse, perforation occurs frequently (see literature by Graham, Lilienthal, Archibald, Alexander, Rienhoff, Longacre, Overholt, Joannides, Bettman and others[1-9]). In the latter instance (method of Willy Meyer), bronchial fistula is less frequent (in dogs, Longacre, using a modified Willy Meyer method without crushing bronchial rings, found that 5.5 per cent developed fistulas but 16.6 per cent died). The method of cutting the cartilaginous rings (Rienhoff[5]) and the cauterization method using silver nitrate (Adams and Livingstone[10]) would seem also to circumvent the lateral tension of the bronchial cartilages. By the use of a plug which conforms in size to the diameter of the lumen of the bronchus, the factor of lateral tension of the bronchial rings is entirely alleviated.

Pressure by the Ligature.—Mass ligation of the bronchial stump is recommended by many (Sauerbruch, Meyer, Archibald, Alexander, Overholt, Carr, Brunn, Shenstone and Janes, Roberts and Nelson) because individual ligation of vessels may at times be impossible or lead to tearing and hemorrhage (Archibald,[3] Rienhoff[5]). In order to effect this type of ligature a great deal of pressure must at times be exerted. This is especially true if induration has occurred about the hilar structures. For this reason special clamps (Carr[12]), silver wire (Archibald[3]) or bands (Heuer and Dunn[17]) have been recommended. Unquestionably, the pressure exerted by the ligature in some instances may cut through the tissue directly or produce necrosis which may lead to a bronchial fistula or hemorrhage.

By the use of bronchial plugs less pressure is needed to tie off the individual bronchi or the entire stump en masse. It follows that there will be less pressure exerted by the ligature and thus a reduction in the hazard of cutting or necrotizing the hilar structures, including the vessels. In an adult lung (male, age 35 years, weight 140 pounds) at autopsy, it took from 2 to 4 pounds pressure to obliterate the secondary bronchi with a suitable plug in place, whereas without the aid of the plug, 6 to 8 pounds of pressure were needed. The pressure needed to collapse the primary bronchi was 3 to 4 pounds with the plug and more than 10 to 12 pounds without the plug. The lungs of this case were considered normal grossly. A similar relationship was found in the dog except that the pressures needed were less; thus, for secondary bronchi, 2 to 3 pounds with plug in place against 6 pounds without plug.

The use of bronchial plugs reduces the amount of pressure needed to obliterate the bronchi by more than half in the normal state. When induration of the hilar structures is present, this difference would be more exaggerated.

The Subserosal Ligature.—Because necrosis of the bronchi not infrequently follows at the site of the ligature or distal to it, many authors tie the vessels distal to the bronchi (Tiegel,[18] Behrend[19]).

In the present work, advantage is taken of the fact that the serosa of the bronchi, the adventitia of the vessels, and the pleura are rich in blood vessels. For this reason, as much of these structures as possible is allowed to remain outside the ligature (Fig. 2). The results indicate that this method is efficacious.

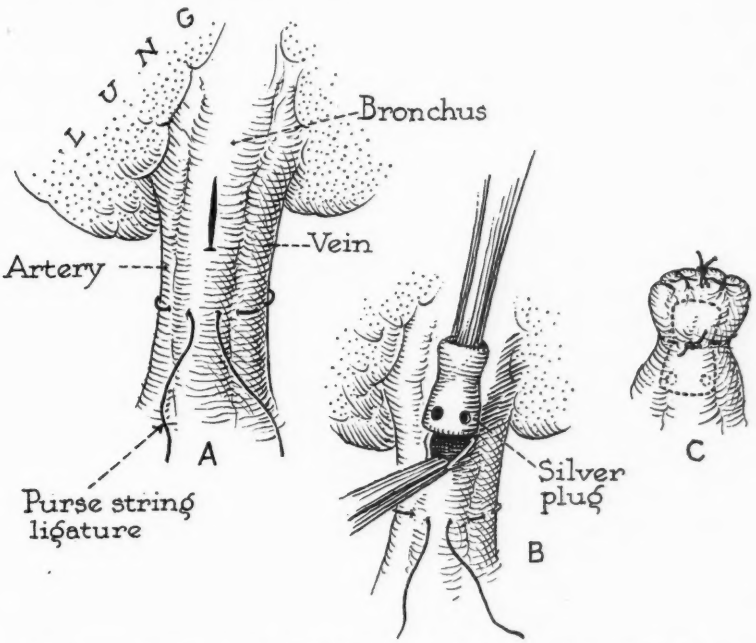

Fig. 2.—*A*, Shows incision into the bronchus and the purse-string suture in place; *B*, insertion of the silver plug into the bronchial aperture; *C*, the bronchial stump is shown with the ligature tied and the bronchus sutured loosely over the plug.

The Intrabronchial-Intrathoracic Pressure Differences.—The fact that there is a negative pressure intrathoracically and a positive one intratracheally creates a pressure differential at the site of the bronchial ligature. In dogs, barking or panting as soon as 12 to 24 hours following operation increases this hazard. Therefore, it was necessary to keep the dogs quiet at least for the first 12 hours following operation. Usually the nembutal used for the operation was sufficient, but if the dog was partially awake following the surgical procedure, morphine was administered. In one dog that was awake at the close of the operation, morphine was not given, and a bronchial fistula developed; the animal subsequently died.

In another series of dogs, in which wax plugs were used and all lobes of one lung removed, daily intrathoracic injections of air up to 450 c.c. in amount were given in an attempt to equalize the intrathoracic and intrabronchial pressures. It was found to be practically impossible to obtain a satisfactory equalization of pressure because of the extremely movable mediastinum in the dog and the thin layer of pleura separating the thoracic cavities.

The Choice of Ligature.—The use of catgut in place of silk, following the same technique that had proved successful, met with failure in two dogs (two lobes each). Bronchial fistulas developed at the site of the ligatures in all four lobes, and the dogs died of a tension pneumothorax. Longacre had a similar experience using catgut and silk in the Willy Meyer method.

COMMENT

Lobectomies, whether in dogs or in human beings, are being performed at the present time with greater ease and with less morbidity and mortality than heretofore. This operation, however, is still a serious one (Graham[1]). In dogs the factor of lateral tension of the bronchial cartilages is perhaps less apparent than it would be in human beings; also the pressure needed to ligate the hilar structures is greater in human beings than in dogs. For these reasons lobectomies are more easily accomplished in the latter. All that we wish to present in this paper is the fact that it is possible to obliterate the bronchi in dogs by the use of silver plugs and that these are removable, leaving a well-healed stump.

This method applied to more than two lobes with the above technique is being attempted and will be reported later.

SUMMARY

A method in which silver plugs are used to close the bronchi in dogs is described.

This method has yielded uniformly good results when two lobes of the lungs were removed.

It is believed that the use of plugs eliminates to a great extent the lateral tension of the cartilaginous rings as well as the pressure of the ligature. These factors of tension and pressure probably tend to produce bronchial fistulas and hemorrhages following lobectomy.

Subpleural, subserosal, and subadventitial insertion of the ligature aids in maintaining the blood supply to the tissues of the lobectomy stump.

REFERENCES

1. Graham, E. A., Singer, J. J., and Ballon, H. C.: The Surgical Diseases of the Chest, Philadelphia, 1935, Lea & Febiger.
2. Lilienthal, H.: Ann. Surg. **66**: 355, 1917; **75**: 257, 1922.

3. Archibald, E.: Ann. Surg. **100**: 796, 1934; J. THORACIC SURG. **4**: 346, 1935.
4. Alexander, J.: Surg., Gynec. & Obst. **56**: 658, 1933.
5. Rienhoff, W. F.: Bull. Johns Hopkins Hosp. **53**: 390, 1933; Arch. Surg. **32**: 218, 1936.
6. Longacre, J. J.: J. THORACIC SURG. **4**: 587, 1935.
7. Overholt, R. H.: J. THORACIC SURG. **5**: 54, 1935-36.
8. Joannides, M.: Arch. Surg. **17**: 91, 1928.
9. Bettman, R. B.: Arch. Surg. **8**: 418, 1924; Surg., Gynec. & Obst. **46**: 602, 1928.
10. Adams, W. E., and Livingstone, H. M.: Arch. Surg. **25**: 898, 1932.
11. Meyer, W.: Arch. Surg. **6**: 361, 1923.
12. Carr, D.: J. THORACIC SURG. **4**: 327, 1935.
13. Sauerbruch, F.: Quoted by Graham, E. A.: Diseases of the Chest, Philadelphia, 1935, Lea & Febiger.
14. Brunn, H.: Surg., Gynec. & Obst. **55**: 616, 1932.
15. Shenstone, N. S., and Janes, R. M.: Canad. M. A. J. **27**: 138, 1932.
16. Roberts, E. H., and Nelson, H. P.: Brit. J. Surg. **21**: 277, 1933.
17. Heuer, G. J., and Dunn, G. R.: Bull. Johns Hopkins Hosp. **31**: 31, 1920.
18. Tiegel, M.: Mitt. a.d. Grenzgb. d. Med. u. Chir. Supplement **3**: 789, 1907.
19. Behrend, A.: Proc. Staff Meet., Mayo Clin. **12**: 391, 1937.

A CATHETER FOR BRONCHOSPIROMETRY

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FRENCKNER and Björkman,[1] and Jacobaeus[2] have developed a procedure designated as bronchospirometry with which the functional capacity of each lung is separately and simultaneously measured and recorded. They have described a specially constructed double bronchoscope for this procedure, and have demonstrated the importance of bronchospirometry, particularly as a preliminary determination in collapse therapy for bilateral pulmonary tuberculosis. Although I had had no experience with this bronchoscope, it seemed that the performance of the procedure could be simplified and made more comfortable for the patient if a flexible instrument were used in place of the rigid double bronchoscope.

I have designed and used a flexible rubber catheter which was kindly constructed by Mr. George L. Winder.* It is fashioned after the principle of the double bronchoscope and made in three sizes (Fig. 1). Its cost should make it available to any institution where bilateral collapse therapy is used.

This catheter is made of rubber and has a natural curve which facilitates its entry into the left main bronchus. A fine steel spring is embedded in its wall, which imparts a desirable semirigidity and makes it noncollapsible. A dividing septum separates the air passage from each lung. The wall contains a fine channel through which two balloons may be inflated, thereby sealing off the left main bronchus and the trachea and thus confining each lung to a separate spirometer (Fig. 2). The catheters are graded in size for large males, average-sized adults, and small females; each is of minimum length so that the dead space is reduced as much as possible.

For a spirometer I have used two "Metabolors".† Fig. 3 illustrates how they are assembled. These are standard metabolism apparatuses and make satisfactory records which permit the calculation of tidal air, supplementary and complementary air, vital capacity, rate of oxygen consumption, and oxygen intake for each lung. However, carbon-dioxide production cannot be calculated without altering the apparatus and performing gas analysis. An ideal spirometer would have to be specially constructed, so that the fluctuations of each bell would be recorded on a single drum of variable speed, so that carbon-dioxide production as well as oxygen intake and ventilation could be measured, and so that lungs of even low capacity would produce fairly wide fluctuations. The latter would necessitate tall spirometer bells of rather small diameter. Such an instrument would be necessary for the precise work of physiologic investigation. For clinical purposes only, however, standard metab-

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*Of American Anode Incorporated, Akron, Ohio.

†Graciously loaned by the McKesson Appliance Company of Toledo, Ohio.

olism apparatuses furnish ample information concerning the functional capacity of each lung inasmuch as carbon dioxide output tends to parallel ventilation while oxygen intake may not.

The Use of the Catheter.—Active laryngeal or tracheobronchial inflammation and left bronchial stenosis contraindicate bronchospirometry. Bronchoscopy is usually

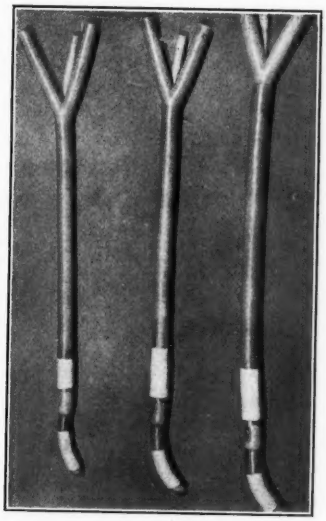


Fig. 1.—Set of three double bronchial catheters.

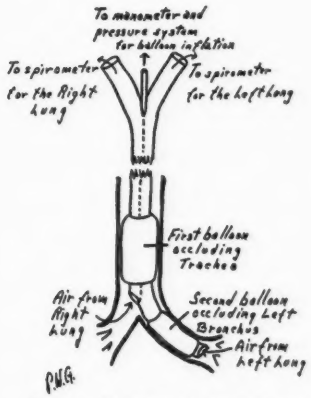

To manometer and pressure system for balloon inflation
To spirometer for the Right Lung
To spirometer for the Left Lung
First balloon occluding Trachea
Air from Right lung
Second balloon occluding Left Bronchus
Air from left lung
P.M.G.

Fig. 2.—Diagram of trachea and bifurcation with catheter in position.

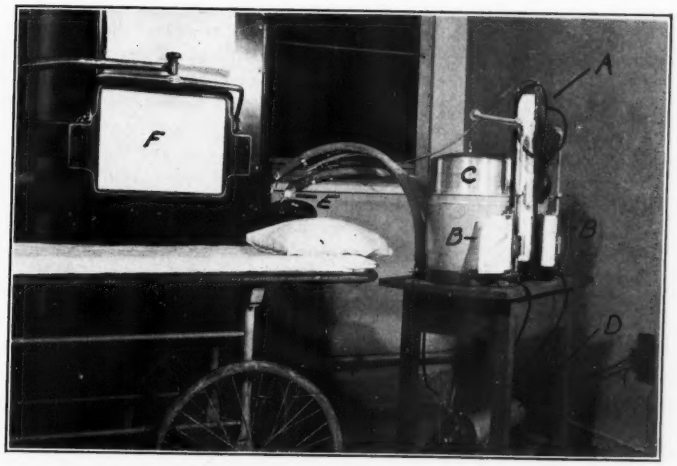


Fig. 3.—Assembled "Metabolors" for bronchospirometry. *A*, Mercury manometer and pressure system for balloon inflation; *B*, kymographic records for each spirometer bell; *C*, bell of one spirometer; *D*, oxygen tank for filling spirometers; *E*, tips to be connected to catheter; *F*, fluoroscopic screen.

performed beforehand; this is not regarded as an additional procedure because potential candidates for bilateral collapse deserve preliminary bronchoscopy. It is advisable to use as large a catheter as possible so that a maximum airway is utilized. Occasionally laryngeal cicatrization prevents the use of the proper size, as does the contraction of the left main bronchus when the left lung is greatly collapsed. Under such circumstances the small catheter has been used.

Postural drainage is performed and expectoration is encouraged as a preliminary to rid the tracheobronchial tree of secretion and exudate. For the same reason it is helpful to do bronchospirometry in the afternoon. Premedication usually consists of a barbiturate and an effective administration of atropine. Morphine is also given to apprehensive patients. Good anesthesia is absolutely necessary and is obtained by pharyngeal and laryngeal spray followed by intratracheal injection. Larocain 10 per cent has proved satisfactory. Following anesthetization, cough and expectoration are again requested. In spite of all measures some patients will continue to produce sputum which may hinder ventilation and even almost fill one side of the catheter. On two occasions this was fortunate, for it determined beyond any doubt which lung was giving rise to sputum, while other methods including bronchoscopy had failed to do so.

This catheter may be sterilized by boiling. Care must be taken to clamp off the balloon channel before immersion. Lubrication is not necessary. If these catheters are given the care any rubber product should have, they can be used repeatedly and stored for long periods. The catheter is inserted into the trachea through an ordinary battery laryngoscope.

The patient then sits upright and is fluoroscoped while the catheter is introduced into the left main bronchus. The catheter has been left in place for more than thirty minutes without particular discomfort to the patient. There is no restriction of motion and any desirable position can be assumed. After insertion of the catheter, it is connected to the spirometers. The balloon channel is attached to a pressure system including a mercury manometer, and inflation of the balloons begun by means of a hand bulb. The proper pressure is predetermined by placing the catheter in glass tubing which surrounds the balloons and approximates the size of the left bronchus and of the trachea. This pressure is usually above 125 mm. of mercury, but varies with the size and age of the catheter and with the size of the patient. With inflation, the left main bronchus is almost immediately sealed off. Before complete inflation, however, the trachea may be sealed off only on expiration when it is smaller. In this manner it is possible for room air to enter the right lung around the upper balloon during inspiration and be expired through the catheter, thereby gradually increasing the right lung spirometer volume and lessening the oxygen percentage of its contents. To avoid this, one may inflate the balloons before connecting the spirometers or inflate them rapidly to the proper pressure. The head of pressure should be diverted from the system once complete sealing of the bronchus and trachea is obtained, so that it will not be expended within the patient should a balloon rupture. This may be accomplished by placing a clamp on the balloon channel or a stopcock on the manometer and trapping the few cubic centimeters of air within the inflated balloons. Another method is to inflate the balloons with a glass syringe using a predetermined quantity of air or asking the patient to signal when air fails to enter the nose or mouth with inspiration. No instance of balloon rupture has occurred. If the catheter is incorrectly placed, that is in the right bronchus, it can be noted on the fluoroscopic screen that it curves to the right when the patient is rotated. In addition, inflation of the lower balloon is almost certain to occlude the right upper and middle lobe orifices long before adequate pressure to seal off the trachea is reached. Such a state of affairs is invariably recognized.

The kymographic record must be calibrated with each spirometer bell so that the ventilatory volumes and the oxygen intake can be recorded. In the apparatus I have used, each small square represents one-tenth minute on the horizontal axis and 100 c.c. of oxygen on the vertical axis. Both kymographs are operated at the same speed by electric clocks. Ventilation is recorded with an inspiratory upstroke and an expiratory downstroke. The volume of ventilation can thus be measured per minute or per cycle. A good idea of the comparative ventilation of the lungs is gained by looking at the record as a whole. Oxygen intake is represented by the climb of the recorded respirations.

The above mentioned authors[1, 2] have demonstrated some facts which are well worth repetition. Normally the oxygen intake, carbon-dioxide output, ventilation and vital capacity of the right lung are 53 to 54 per cent, and the left 46 to 47 per cent of the total for both lungs. The roentgen examination may be very misleading if one attempts to interpret it on a functional basis. There is no way of knowing with certainty the functional capacity of each lung without bronchospirometry. Carbon dioxide output and ventilation seem to follow each other. Oxygen intake varies more, and is the first function to be altered in diseased states. A huge cavity tends to diminish the function of a lung, apparently absorbs little or no oxygen, and does secrete carbon dioxide. Diaphragmatic paralysis may cause a marked reduction in ventilation and at the same time interfere only slightly with gaseous interchange. The latter seems to parallel the intactness of the pulmonary parenchyma. The function of a given lung may eventually be better after thoracoplasty than before. This operation as well as pneumothorax diminishes the functional capacity of the contralateral lung. Jacobaeus, Frenckner, and Björkman call attention to the poor coughing power accompanying extensive fibrosis and massive cavitation as evidenced by meager fluctuations on the part of the diseased lung. While such performance undoubtedly signifies a weak coughing power, it does so indirectly for only fluctuations are recorded. The patient has no way of closing the glottis and building up an intrathoracic pressure to be suddenly released as an expellant force. In addition, this force reaches an appreciable magnitude only in the larger bronchi, and secretions in the parenchyma and small bronchi are expelled by a compressive action called the "tussive squeeze" by Chevalier Jackson.[3] This action is frequently visualized through the bronchoscope deep in the lower lobes and is not recorded by bronchospirometry.

The following brief case reports and records demonstrate the clinical applicability of this catheter to the procedure of bronchospirometry.

CASE 1.—C. H., a 17-year-old colored male, had a history of short duration and sputum containing tubercle bacilli. A chest roentgenogram, Fig. 4, disclosed a light infiltration in the left apex. Bronchospirometry was done in the recumbent position with the medium catheter. The ventilation and vital capacity of the left lung were almost normal. Its oxygen intake, however, became only 38 per cent of the total of both lungs (Fig. 5).

CASE 2.—J. G., a 35-year-old colored male, had a right phrenicectomy and thoracoplasty in 1932 for a large apical cavity. In Fig. 6 a cavity is visible behind the unresected rib stumps and transverse processes. The infiltration in the left midlung had remained unchanged for years. Although there appears to be considerable aerated lung on the right, the patient's vital capacity is only 1,200 c.c. or 29 per cent. Secondary thoracoplasty would be hazardous if it would further diminish this capacity. Bronchospirometry was performed in the recumbent position with the

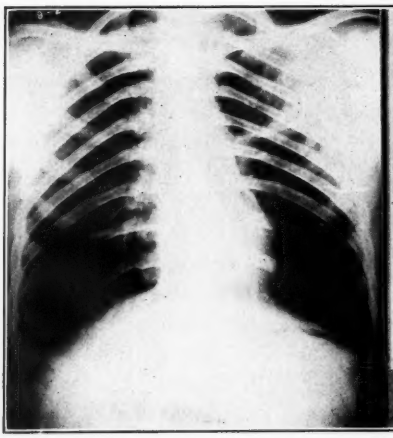


Fig. 4.

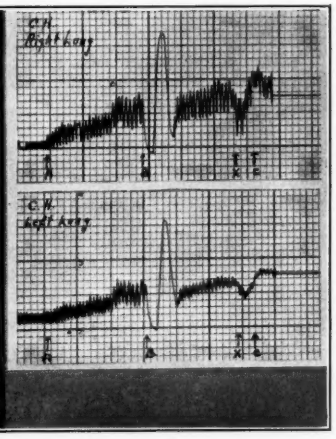


Fig. 5.

Fig. 4.—Case 1, C. H. Early infiltration of the left apex.

Fig. 5.—Case 1, C. H. *A*, Inflation of balloons; *B*, maximum expiration and inspiration; *X*, requested coughing; *C*, deflation of balloons. Of the total vital capacity (3400 c.c.) and oxygen intake (385 c.c. per minute) the right lung furnishes 53 per cent and 62 per cent respectively, the diseased left lung 47 per cent and 38 per cent.

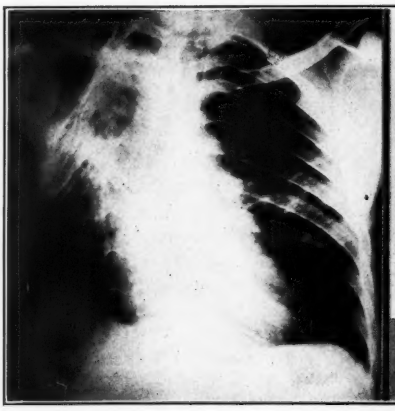


Fig. 6.

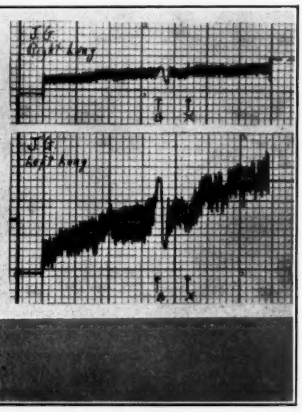


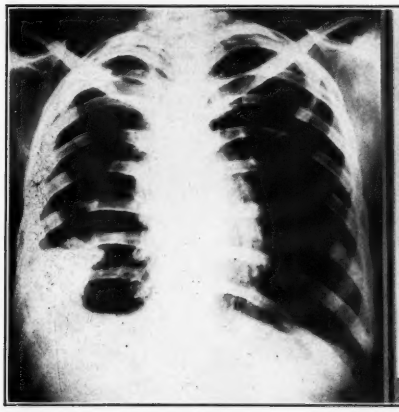
Fig. 7.

Fig. 6.—Case 2, J. G. Old type of thoracoplasty with residual cavity in apex.

Fig. 7.—Case 2, J. G. Balloons inflated before connection of spirometers. *B*, Maximum inspiration and expiration; *X*, requested coughing. Of the total vital capacity (1250 c.c.) and oxygen intake (370 c.c. per minute) the right lung furnishes only 20 per cent and 12 per cent respectively.

medium catheter (Fig. 7). This shows the function of the right lung to be much reduced. Only 12 per cent of the total oxygen intake takes place on the right side probably because of aeration of the cavity and diminished ventilation of the base secondary to hemidiaphragmatic paralysis. Revision thoracoplasty can probably be safely undertaken.

CASE 3.—B. W., a 23-year-old colored female, had a vital capacity of less than 900 c.c. (standing). She was admitted with extensive bilateral disease which was controlled on the right side with pneumothorax. A huge cavity remains in the left apex (Fig. 8). The sputum contains tubercle bacilli. Because of the low vital capacity, any collapse on the left would be dangerous unless the partially collapsed right lung were functioning surprisingly well. Bronchospirometry was performed in the recumbent position with a small catheter (Fig. 9), which indicates that in spite of the huge apical cavity almost all of the patient's pulmonary capacity is furnished by the left lung, the collapsed and fibrosed right lung accounting for less than 20 per cent of the total vital capacity and only 11 per cent of the oxygen intake. The only solution for this patient is partial re-expansion of the right lung and a repeat bronchospirometry. If the total functional capacity should be increased, we must be sure that the right lung partakes in that increase for it is known that the contralateral lung benefits from the diminution of a collapse.



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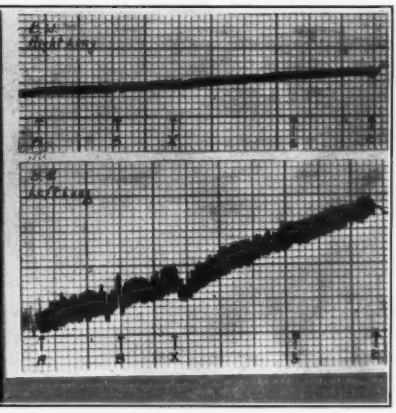

Fig. 9.

Fig. 8.—Case 3, B. W. Marked collapse of the right lung with pleural effusion; huge cavity left apex.

Fig. 9.—Case 3, B. W. *A*, *B*, *X*, and *C* as in Fig. 5; *S*, Patient turned on the left side. Of the total vital capacity (775 c.c.) and oxygen intake (360 c.c. per minute) the right lung furnishes 20 per cent and 11 per cent respectively.

This patient was turned on the left side during the procedure (*S*, Fig. 9). There seems to be no change in the function of the right lung. The tidal volume of the left is slightly decreased and the respiratory rate increased. A faster drum and a spirometer with wider fluctuations would have produced a record which would be much easier to analyze.

CASE 4.—T. R., a 49-year-old white male, had tubercle bacilli in his sputum and a vital capacity of 2,100 c.c. or 48 per cent. A left phrenic crush had been done three months previously. Fig. 10 shows extensive cavitation to the left eighth rib. Pneumothorax failed. Because of pulmonary emphysema, age, extent of the disease, and the vital capacity, one would hesitate before doing a thoracoplasty. Broncho-

spirometry was performed with a large catheter (Fig. 11). This indicates that the diseased left lung has a vital capacity of only 550 c.c. and is the site of only 12 per cent of the total oxygen intake, and extensive collapse can probably be safely applied.

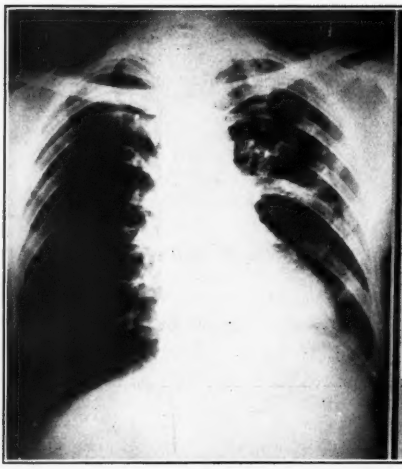

Fig. 10.

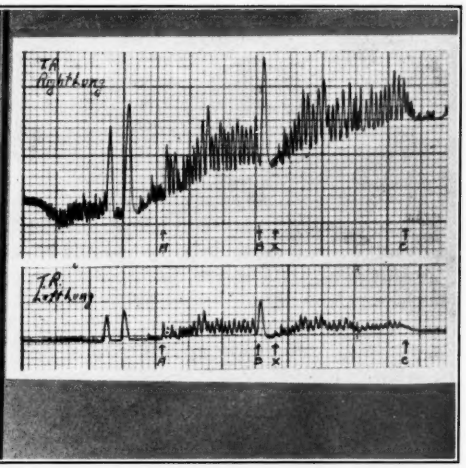

Fig. 11.

Fig. 10.—Case 4, T. R. Pleural fibrosis, extensive cavitation, and an elevated diaphragm can be visualized on the left.

Fig. 11.—Case 4, T. R. *A*, *B*, *X*, *C* as in Fig. 5. Of the total vital capacity (2100 c.c.) and oxygen intake (390 c.c. per minute) the right lung furnishes 75 per cent and 87 per cent respectively.

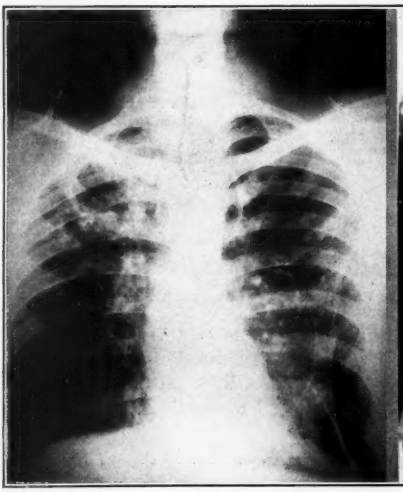

Fig. 12.

Fig. 13.

Fig. 12.—Case 5, H. R. At time of bronchospirometry.

Fig. 13.—Case 5, H. R. After thoracoplasty. Left pneumothorax partially expanded.

CASE 5.—H. R., a 46-year-old white male, had bilateral pulmonary tuberculosis of two years' duration. Pneumothorax failed on the right side and a phrenic crush was done. Pneumothorax was then started on the left (Fig. 12). The pleural pocket was irregular; it was maintained with 400 c.c. of gas per week. The cavity on the right remained open and the sputum continued to be positive for tubercle bacilli. Vital capacity was 50 per cent of normal. Bronchospirometry was performed with a large catheter and revealed that the left (pneumothorax) lung was supplying 66 per cent of the total oxygen intake and 70 per cent of the vital capacity. Thoracoplasty was performed on the right in four stages (Fig. 13). Stereoroentgenograms of the left did not show cavitation and the pneumothorax was abandoned. Certainly one would have hesitated before doing such a thoracoplasty if he were not aware that the lung already partially collapsed was supplying most of the patient's pulmonary function.

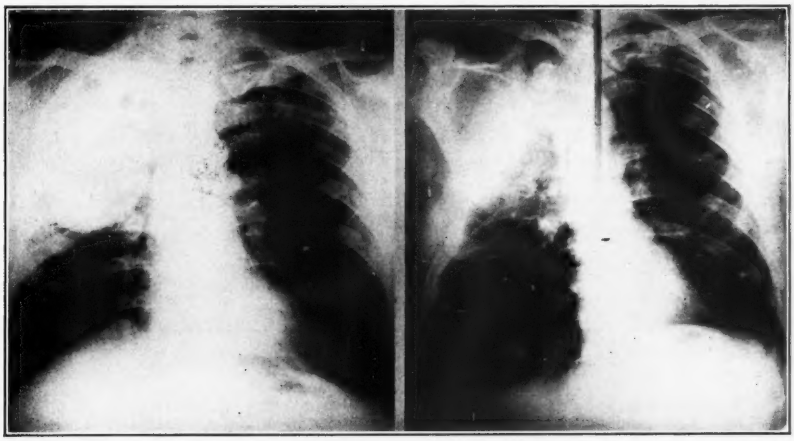

Fig. 14. Fig. 15.

Fig. 14.—Case 6, J. M. At time of bronchospirometry. Honeycombing in left apex.
Fig. 15.—Case 6, J. M. After removal of paraffin and thoracoplasty.

CASE 6.—J. M., a 50-year-old white male, had bilateral pulmonary tuberculosis for two years with a large cavity in the right apex. Right pneumothorax was discontinued because it was ineffective. Vital capacity was 61 per cent. A paraffin pack was done Nov. 6, 1937, on the right because of the patient's age, honeycombing in the left apex, and emphysema (Fig. 14). Following this bronchoscopy showed the positive sputum to be coming from the right side. At this time the patient's vital capacity was 50 per cent of normal. Bronchospirometry was done in the sitting position with a large catheter. This indicated that the right lung was furnishing only 23 per cent of the total vital capacity and 30 per cent of the total oxygen intake, so that the paraffin was removed and a thoracoplasty performed without trepidation (Fig. 15).

CASE 7.—A. K., a 22-year-old white female, had bilateral pulmonary tuberculosis for six years. The disease on the right side was considered controlled by pneumothorax, which was started in 1936 and twice augmented by pneumonolysis. Pneumothorax failed on the left. A phrenic avulsion had been performed on the left side in 1933. There was extensive cavitation of the left upper lobe (Fig. 16). The patient's

vital capacity was 1,100 c.c. or 34 per cent. Bronchospirometry was performed with a small catheter in a sitting position and revealed that the much collapsed right lung was furnishing 45 per cent of both the vital capacity and the oxygen intake. Extrapleural pneumothorax on the left, therefore, was considered safe and was done. The upper lobe could not be separated anteriorly (Fig. 17) and the collapse obtained was ineffectual; however, it was well tolerated until a slight spread occurred in the right lung. Thereafter both forms of pneumothorax had to be discontinued because of dyspnea.

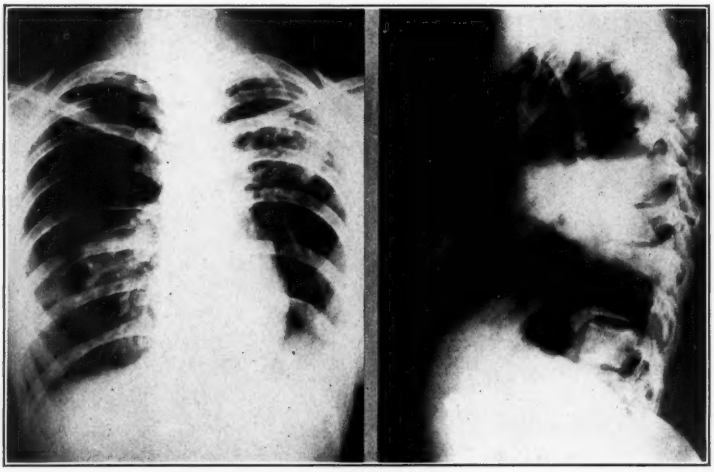

Fig. 16. Fig. 17.

Fig. 16.—Case 7, A. K. At time of bronchospirometry.
Fig. 17.—Case 7, A. K. After ineffectual extrapleural pneumothorax.

REFERENCES

1. Frenckner, Paul, and Björkman, Stig: Bronchospirometry and Its Clinical Application, With a Short Account of Bronchial Catheterization, Proc. Roy. Soc. Med. **30**: 477, 1936.
2. Jacobaeus, H. C.: Bronchospirometry, J. THORACIC SURG. **7**: 235, 1938.
3. Jackson, Chevalier, and Jackson, C. L.: Bronchoscopy, Esophagoscopy and Gastroscopy, Philadelphia, 1934, W. B. Saunders Company.

BRONCHIOGENIC CARCINOMA OF MORE THAN FIVE YEARS' DURATION TREATED BY RADIOTHERAPY

Report of a Case

Fred R. Harper, M.D., F.A.C.S.
Denver, Colo.

IT IS doubtful if radiotherapy has ever effected a cure in a case of primary carcinoma of the bronchus or lung. Neither have the palliative results entirely justified this method of treatment. Leddy and Vinson reported a group of thirty-two patients who received radiotherapy. The longest duration of life was four years, while the average was slightly more than eight months. In a similar group of twenty-nine untreated patients the longest duration of life was thirty-one months with an average of a little more than five months. Graham's observation, that the duration of a bronchial carcinoma in untreated cases is extremely variable, makes it difficult to evaluate statistics on the duration of the disease. The reason for this variability is not clearly understood. In a study of twenty-six untreated cases Carlson and Ballon found six cases that survived two years or more after the onset of their symptoms. The longest was five years.

Graham has asked that reports of cases of primary carcinoma of the bronchus or lung treated by radiotherapy present incontrovertible evidence of the existence of the malignancy. I feel that the case I am reporting fulfills this requirement.

The patient was a male, aged 63 years, who was examined at the Mayo Clinic in September, 1930. He gave a history of having developed sharp pain in the right side of the chest followed by hemoptysis in April, 1929. He had raised large amounts of sputum continuously and had had four definite attacks of hemoptysis. Since the onset of his symptoms, he had run a high temperature at intervals; his temperature had been as high as 104° F. During the winter of 1929 his weight had decreased from 175 to 139 pounds, most of which he had regained.

X-ray examination at the time of his admission to the Mayo Clinic showed a bronchiectasis of both lower lobes. He was bronchoscoped and found to have an infiltrating, bleeding ulcerative lesion at the bifurcation of the trachea, extending into the right main bronchus. The tissue removed from this growth was reported as Adenocarcinoma Grade III.

At that time he received one course of x-ray treatments, which consisted of four treatments at daily intervals, 200 kilovolts, one hour and ten minutes' duration each time. The radiotherapy treatments were continued by Drs. F. B. Camp and P. F. Cole of Springfield, Mo., until January, 1932. They report that there was a decided improvement in the patient's condition following each treatment.

The patient was seen at the Thomas-Davis Clinic Nov. 1, 1935. He had been growing gradually worse during the past few months and was raising a large

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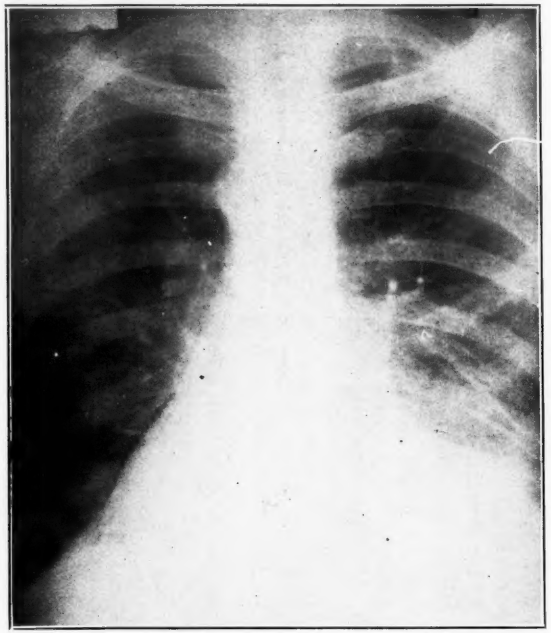

Fig. 1.—Roentgenogram of the chest taken in 1931 while the patient was receiving radiotherapy.

Fig. 2.—Roentgenogram of the chest taken in 1935 just prior to drainage of the lung abscess.

amount of purulent sputum. A culture of the sputum showed many short and long chain streptococci. Roentgenograms taken following the administration of pneumoperitoneum showed a dense homogeneous shadow in the right lung, which extended from the region of the hilus to the third interspace and down to the base. This shadow fused with the heart shadow medially. Below the diaphragm there was evidence of the air which was injected into the peritoneal cavity prior to taking the roentgenograms. From the findings it was evident that there was an extensive lung abscess superimposed upon the carcinoma. Because of the distressing cough it was thought best to drain the pulmonary abscess. This was done through an incision over the tenth rib posteriorly. After removal of a segment of the tenth rib, an incision through the pleura opened a large abscess cavity. The patient died three weeks following the operation.

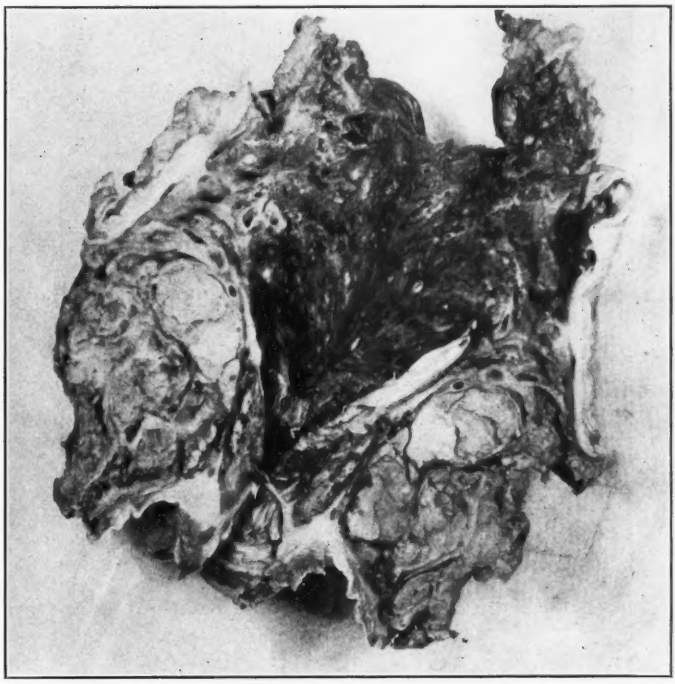

Fig. 3.—Gross specimen of the malignancy of the lung. The definite encapsulation may be noted.

At post mortem a large carcinoma 11.5 cm. in diameter was found at the base of the right lung. The carcinoma involved, but did not extend through, the diaphragm. At the costophrenic angle there was a large abscess cavity which had been drained. There was a dense capsule ½ cm. thick which surrounded the malignant tissue, except in the region of the abscess cavity, and separated it from the surrounding lung tissue. The malignancy had apparently not broken through this thick fibrous capsule. Metastases to other organs were not found. Microscopic study of the autopsy material compared with the biopsy removed in 1930 showed it to be the same type of carcinoma. It was thought that the growth of the malignant tissue had been retarded by the radiotherapy.

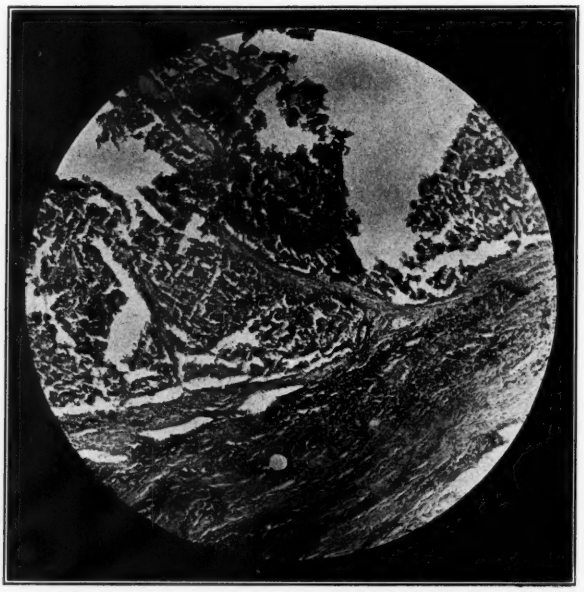

Fig. 4.—Photomicrograph of the malignant tissue removed at necropsy. The surrounding capsule through which the malignant tissue has not spread may be noted.

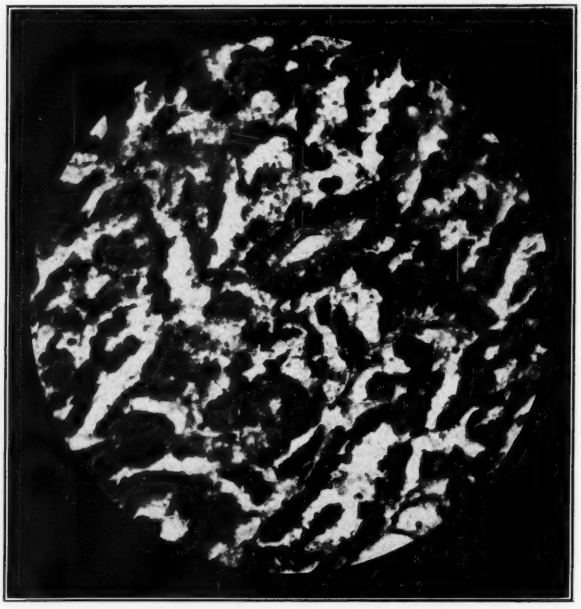

Fig. 5.—Photomicrograph taken under high magnification to show the cellular structure of the tumor tissue.

A case of primary carcinoma of the bronchus is reported. The case is of interest because of its unusually long duration. The duration was seven years from the onset of the symptoms, and five years and four months from the time the biopsy was taken. During this time the patient received repeated radiotherapy treatments, which were thought to be effective. The absence of metastases at the post-mortem examination, and also the fact that the carcinoma was so completely encapsulated within the lung tissue, were considered to be evidence of the effectiveness of radiotherapy in this case.

Fig. 6.—Photomicrograph taken under high magnification to show the cellular structure of the tumor tissue.

[Editorial Note: This case report is published because it is a good example of why the literature on this subject is as confusing as it is. The type of tumor described here is one which would seem to belong to that group designated by Womack and Graham as mixed tumor (Mixed Tumors of the Lung: So-called Bronchial or Pulmonary Adenoma, Arch. Path. **26**: 165, 1938). These tumors are often present for many years as benign growths before they present evidence of invasion or of metastasis. In many instances mitotic figures are infrequent even when the tumor is associated with distant metastases. There is little or no evidence to indicate that in this case the x-ray therapy had any influence on the tumor despite the author's conclu-

sions. On the other hand, in this type of case surgical removal offers an excellent prognosis if the operation is performed before distant metastases have occurred.—E. A. G.]

The author is indebted to Drs. P. P. Vinson, H. J. Moersch, and F. P. Camp for the early history of this case.

REFERENCES

1. Carlson, H. A., and Ballon, H. C.: The Operability of Carcinoma of the Lung, J. THOR. SURG. **2:** 323, 1933.
2. Graham, E. A.: The Diagnosis and Treatment of Primary Carcinoma of the Bronchus or Lung, Am. J. Roentgenol. **31:** 145, 1934.
3. Leddy, E. T., and Vinson, P. P.: The Roentgen Treatment of Bronchiogenic Carcinoma, Am. J. Roentgenol. **30:** 92, 1933.

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